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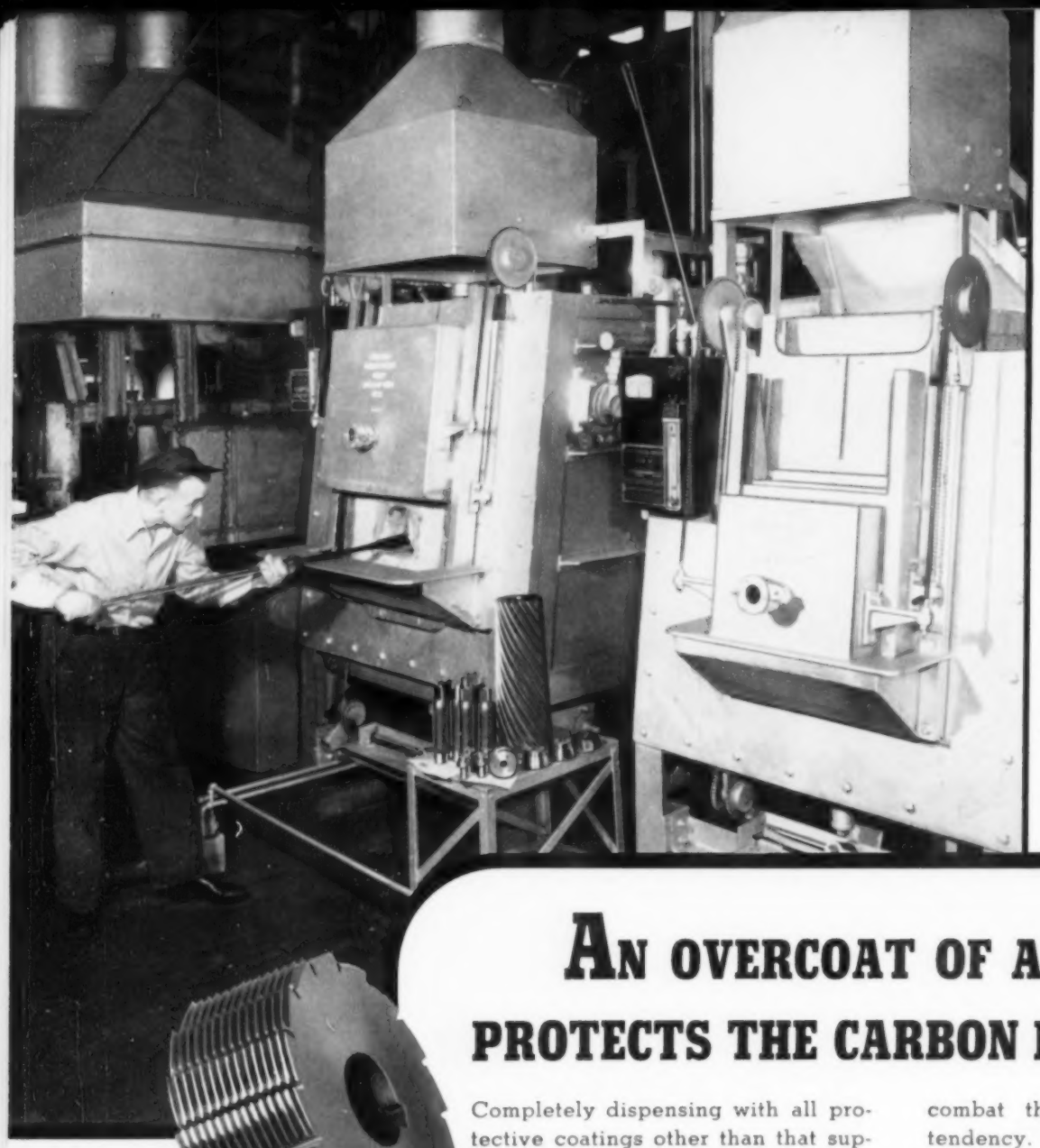

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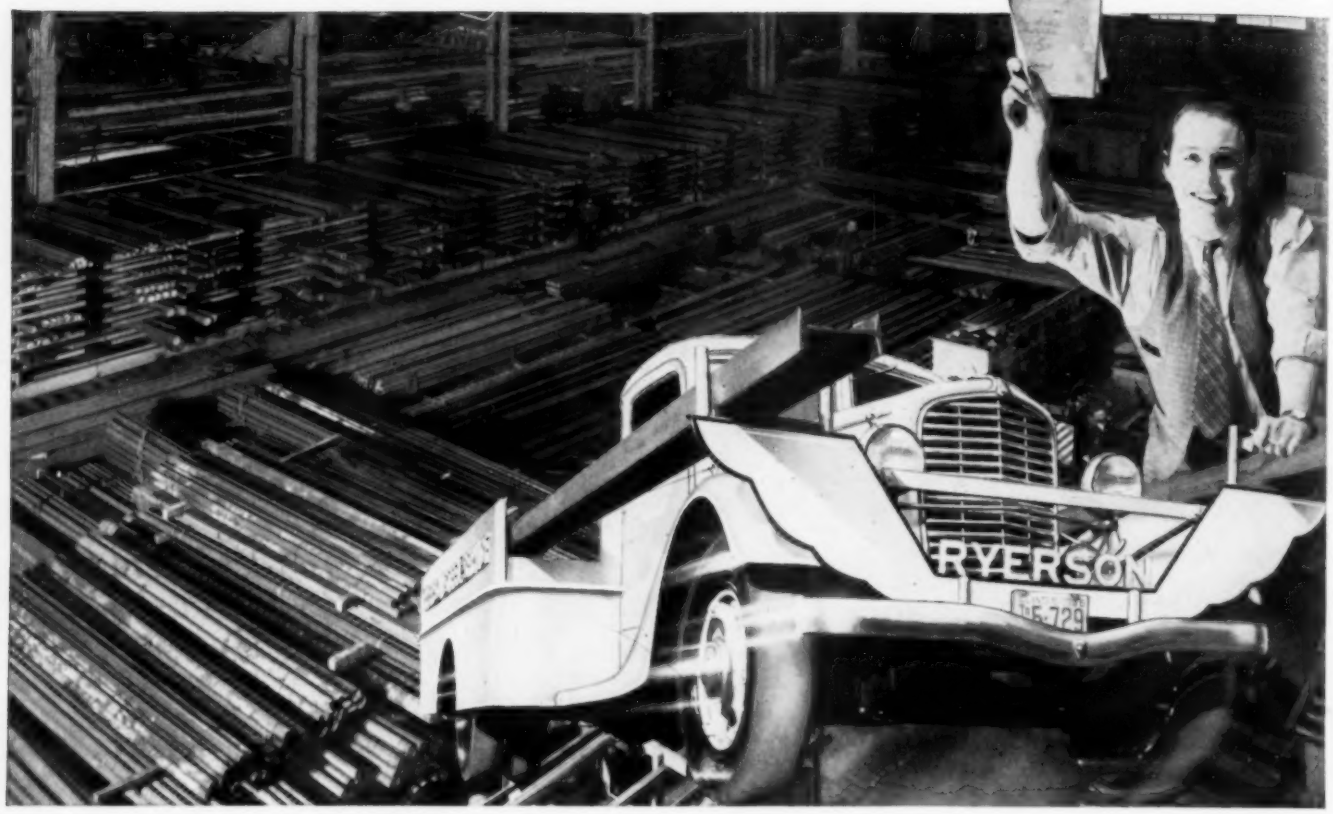

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CONTINUOUS HEAT TREATING MACHINE QUICKLY BUILT FOR EMERGENCY SERVICE

By Horace C. Knerr
Consulting Metallurgical Engineer
President, Metlab Co.
Philadelphia

AN URGENT ORDER of large size, recently obtained by the author's company in Philadelphia, required us to install a new heat treating furnace of special design. The best deliveries obtainable from furnace manufacturers ranged from three to five months. We built the furnace in two months time, from the completion of preliminary sketches to the starting of the first load through for production. Actually, part of the furnace (the tempering end) was completed first and placed in operation within five weeks. While awaiting the quenching end, existing batch furnaces were utilized for the quenching operation. Thus mass production was achieved in a surprisingly short period.

This furnace, or heat treating machine, consists of three parts, which function respectively as a pre-heating and saturation furnace, a quenching device and a tempering unit. Operation is entirely automatic from the time material enters the pre-heating end until it is discharged from the tempering furnace. Work is moved continuously from one end to the other at regulated speed. Both furnaces are gas fired, with a quenching temperature of about 1600° F. maximum. The installation has a capacity exceeding 1000 lb. per hr. or 12 tons per day on 24-hr. operation, and it will handle parts of a size up to about 5 in. diameter and 2 ft. long. (Parts of larger diameter can be accommodated by slight alterations.)

Adaptability to heat treat such work as will be required by the American preparedness plan is an important feature of timely interest. This applies particularly to forgings, castings, or rough machined parts of uniform size and shape and moderate weight.

Early completion being of paramount importance, it was necessary to design the furnace to utilize only such parts and materials as could be obtained from warehouse stock. Heat resisting alloy, all of 18% chromium, 8% nickel stainless steel, was limited to standard angles, sheets and bars. The shell, burner equipment, and hearth of an old pusher type furnace, originally constructed for a different purpose but abandoned, were utilized in the construction of the quenching end; likewise the drive and variable speed control of this old furnace was available. However, the mechanical movement of the charge, the pre-heating section of the leading furnace, the temperature control, blower system, and quenching arrangements were constructed new. All of the remainder of the unit, including the quenching tank with its conveyor mechanism and the tempering section, was of entirely new construction.

High Temperature Section

The high temperature section includes a charging platform, pre-heating zone, heating up zone, and saturating zone in the furnace itself.

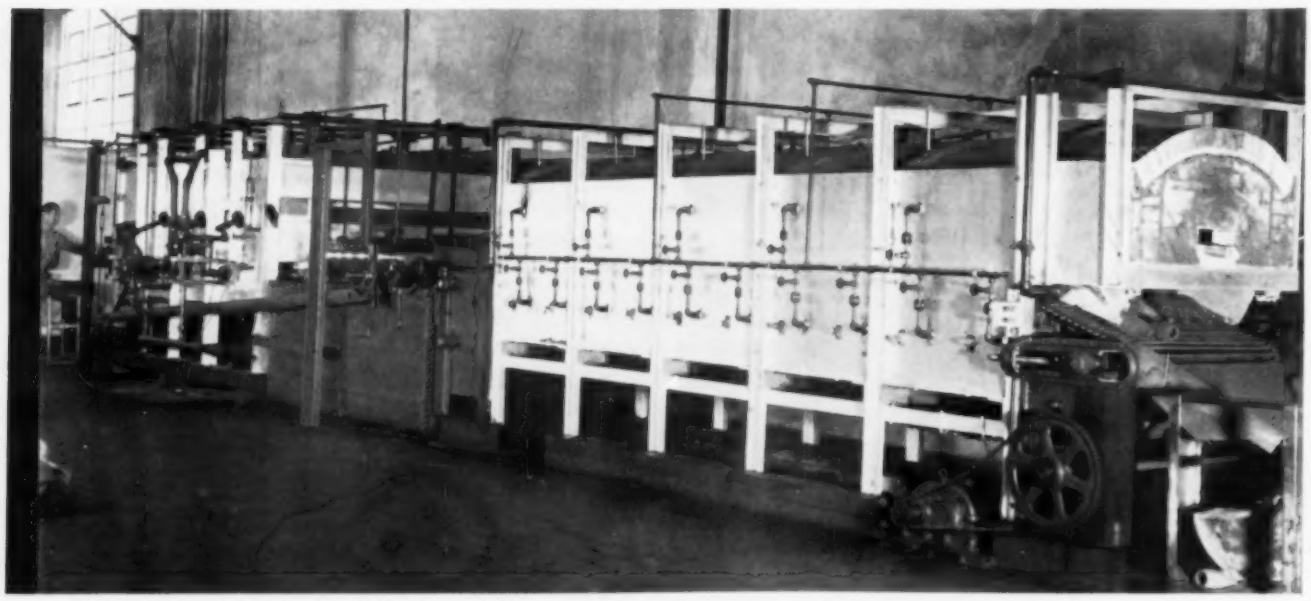
A simple conveyor system of unique design reduces the usual heat losses. Work travels through this high temperature section on a series of light trays made of 18-8 shown in the operator's hands on the opposite page. These weigh about 4½ lb. apiece and each one carries a load equal to about ten times its own weight. They are carried forward by intermittent motion provided by a simple mechanism (later to be described) with a minimum of moving parts. At the quenching end, the trays leave the furnace with the work, but the propelling mechanism remains at all times in the heating zone. As a result, only about 10% of the useful heat is carried out by the conveyor. This is a great advantage over many furnaces with belt conveyors, especially those using heavy links or pans, where the heat loss through the conveyor system may exceed the heat required for the charge itself.

A new continuous automatic furnace was recently placed in operation at Metlab's plant for mass production heat treatment of forgings, castings, or rough machined parts of uniform size, under closely controlled time and temperature conditions. Its special details of design reduce the usual heat losses. Of timely interest is that this equipment is especially well adapted to handle, at low cost, work such as will be required by the American preparedness program.

The mechanism used for pulling the trays through the furnace is designed and operates as follows:

A channel-shaped member made by welding together two stainless steel angles runs down the length of the furnace on each side. Each channel is hung edge-wise from five swinging vertical rods passing through the furnace arch to overhead supports. A sealing device consisting of two plates prevents loss of heat and gases through the slots through which these hangers pass; the lower plate fixed to the brickwork is slotted, while the one on top of it has a hole closely fitting the hanger bar and slides forward and back with the latter.

Each hanger is attached at its upper ends to an arm extending horizontally from one of five shafts crossing the top of the furnace from one side to the other. These shafts are caused to oscillate through a small angle by bell cranks connected to a single pull bar. Simultaneous lifting of all of the hanger bars (and therefore of the two longitudinal channels) is secured by a master pull rod actuated by a cam on the main drive shaft.



General View of Hardening Furnace, Quench Tank, and Drawing Furnace

Synchronized with the up-and-down motion of the longitudinal channels in the furnace is a forward-and-back motion obtained by means of a pair of cams, also on the main drive shaft. These cams, through a simple mechanism, actuate a pair of cables which pass to the discharge end of the furnace and are there attached to the extending ends of the longitudinal channels, so that these are subject only to tension when moving the charge, thus keeping them straight and avoiding buckling. (Counterweights move the channel bars back to the starting position.)

Each of the longitudinal channels is provided with a series of pins or fingers which extend downward and engage with hooks on the leading edges of the work-carrying trays. Forward motion of the channel bars therefore slides all of the trays forward one space, simultaneously. In a full furnace the tray in No. 1 position is always quenched at the end of this stroke and a new tray at the loading end is started on its way. The channels then lift so the fingers disengage the trays; the channels move back, and then are lowered again to engage the trays in readiness for another forward stroke.

Trays slide through the furnace on bars of heat resisting alloy. Wear has been found to be slight and can be repaired by welding on a little stellite. In fact, any of the working parts can be readily replaced. The trays themselves are not quenched, but, after discharging their load into the quench tank, move onto a rack where they cool gradually and are returned at intervals to the loading end by the operator as he makes his rounds.

Simplified furnace control is an important feature. Rate of travel through the furnace is easily regulated. The stroke or forward motion is, of course, adjustable. The speed of operation is controlled by regulating the time cycle through the aid of a Reeves variable speed control on the main drive.

Work is gradually pre-heated in a section of the furnace about 5 ft. long by gases moving forward toward the door from the high temperature zone. This preheating brings the work temperature up to about 800° F., thereby accomplishing considerable fuel economy. The high temperature zone is fired by two banks of burners, each bank regulated by an automatic controller. One bank serves the heating up zone and the other the saturating zone.

In addition to the two control thermocouples, there are six thermocouples placed 24 in. apart through this furnace, connected to a Leeds and Northrup multiple point recorder for permanent temperature record, and for checking. The same recorder gives a permanent record and check of the temperatures in the tempering furnace.

The furnace proper has a hearth underfired with six burners (three from either side) as well as an equal number of inclined burners firing just under the roof or arch. This arrangement provides excellent uniformity in heating a charge. It avoids the objection common to many over-fired conveyor furnaces wherein the charge is bound to be hotter on the upper surface than on the lower. This is particularly important in handling parts of considerable bulk or weight. The present furnace will uniformly heat parts as high as 10 in. stood on end.

A flame curtain at the quenching end aids in controlling the furnace atmosphere and also prevents loss of temperature by radiation or otherwise in that part of the charge which is about to be quenched.

Operator Is Placing a Tray on Charging Platform Prior to Loading Bottle Shaped Castings Between Comb-Like Separators. At either side may be seen the end of the channel-shaped members, with pins extending downward, that engage the hooks on the trays and pull them forward in unison through the furnace. Levers for raising channels are at top

Quenching Section

Considerable care was given to the design of the auxiliary equipment needed in the quenching operation in order to insure the best results.

Individual pieces being treated are placed upon the trays, separated and uniformly spaced by means of the comb-like fixture at the entrance shown in the view on page 149. When quenching, the first tray moves forward and then drops the work by a hinging action in such a way that each piece falls into a trough guiding it individually into the quenching oil. At the bottom of this trough, each piece falls on a flight conveyor under the oil; it is held separately by a series of fingers so the hot parts do not come in contact during quenching; likewise the oil circulates freely all around. This separate heating and quenching insures uniformity, piece to piece, and avoids soft spots in the work which might otherwise occur with some material if dumped promiscuously.

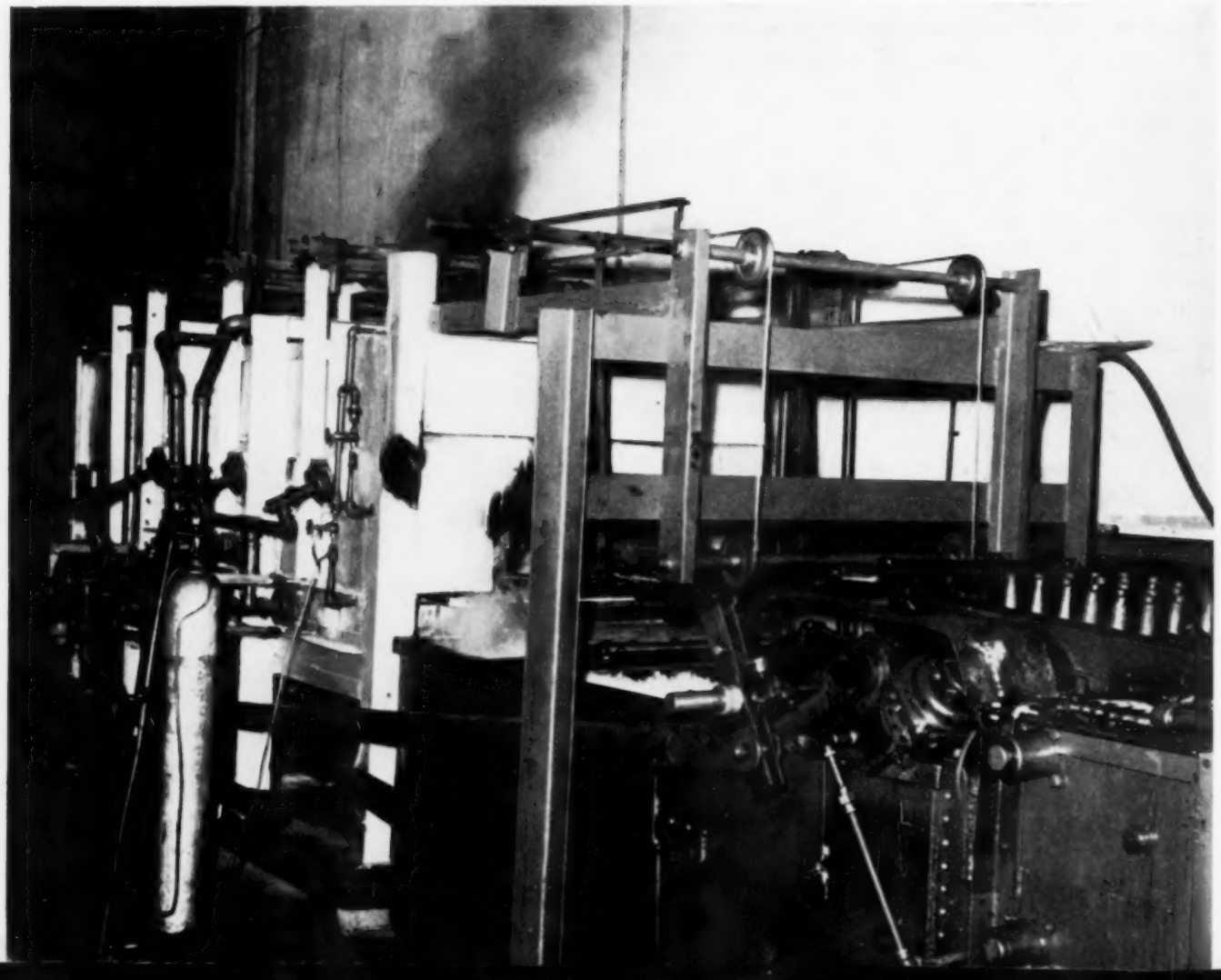
Strong circulation of the quenching oil is obtained by a ¾-hp. motor driving a shaft upon which are mounted two 4-in. propellers. This shaft and the propellers are extended into a tubular, water-jacketed cooler, an arrangement which enhances the efficiency of the propellers as a circulating medium, and passes the oil rapidly over the cooling surface. Additional cooling coils made of copper tubing are disposed in the tank itself. A pair of these stirring motors and cooling jackets is provided so that a spare is always available should one get out of order.

A reciprocating bar, actuated by means of a crank on the main drive shaft previously mentioned, operates the flight conveyor by means of a ratchet and pawl. The motion is timed so that the conveyor is at rest when the charge is deposited and moves shortly thereafter. The quenched work remains under the oil during several cycles, thus giving it ample time to cool. Continued motion of the conveyor brings the quenched work above the level of the oil where it has time to drain thoroughly before entering the tempering furnace.

Tempering Section

At the top of the flight conveyor the work is transferred to a series of chutes which guide the individual pieces onto another conveyor

Discharge End of High Heat Furnace and Quenching Tank. Details of mechanism for moving load through furnace (as described in the text) may be observed, especially the cables for pulling the channel-shaped side members forward, and the overhead shafts for hanging same and giving them the required up-and-down motion



mechanism which carries them through the tempering furnace. This conveyor, which is exposed to lower operating temperatures than the mechanical parts in the quenching furnace, consists of a series of transverse bars of 18-8 steel whose ends are attached to the links of an endless chain along each side of the furnace. Each chain travels in a recess in the wall and never reaches a temperature of more than 300 or 400° F., being well shielded and also cooled by a water pipe.

This chain conveyor, which returns under the furnace, is driven by an independent motor and speed regulator synchronized with the speed of the quenching section of the machine. Both drives may be stopped by the operation of a single push button.

At the discharge end of this furnace, work may be dropped directly into a quenching tank (if this is required for certain types of steel that are susceptible to temper brittleness) or allowed to cool more slowly while remaining on that portion of the chain which extends beyond the furnace proper. The choice between a sudden fall and quench from the tempering zone, or a gradual carrying away from that zone, is determined by the slope of the chain and roller conveyor at this exit.

This tempering section is heated by means of 30 small inspirator burners, 20 of which fire in a series of 10 from each side into a combustion space under the hearth while the rest fire under the arch, thus, again, providing a very uniform heating on all sides of the work. These burners are divided into two banks, one for preheating and one for saturating.

A series of six thermocouples spaced along this furnace is connected with the Leeds and Northrup multiple point recorder so that the latter gives a complete and continuous record of the entire heat treating operation.

Additional Facts of Interest

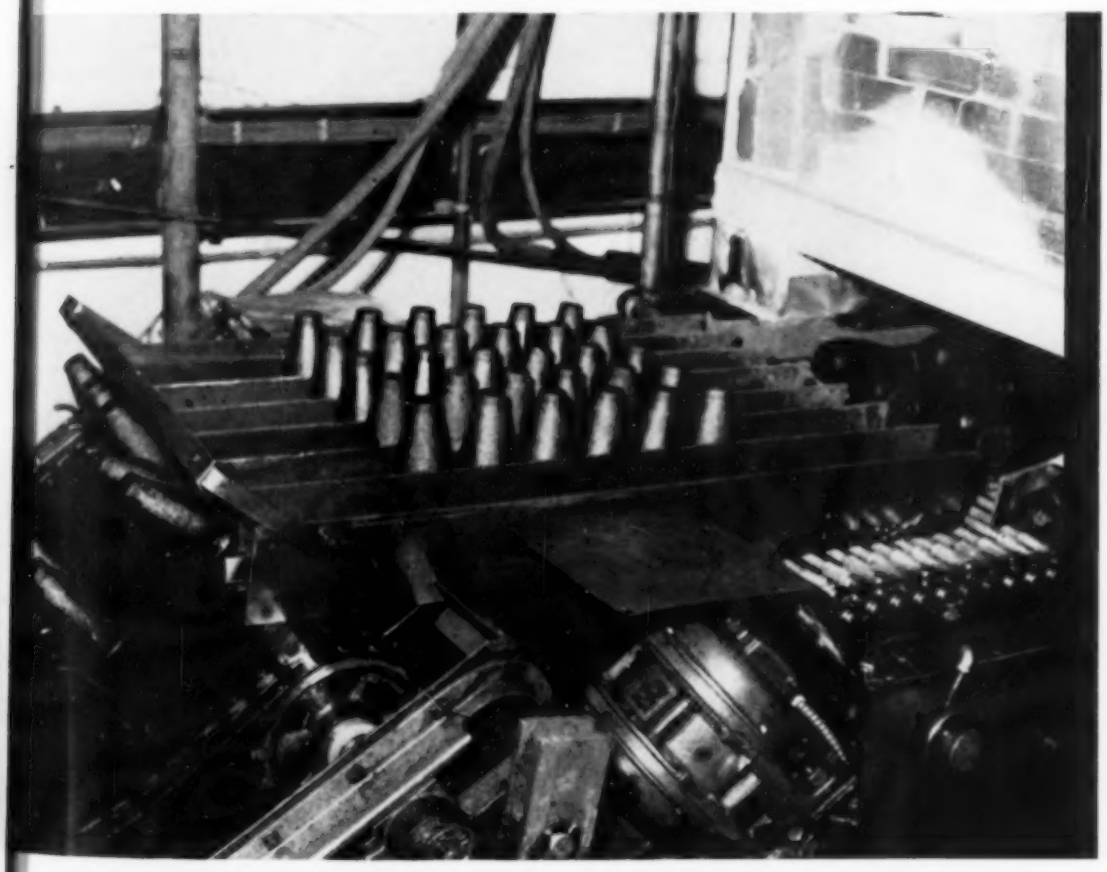
Heating Methods Employed. The quenching or high temperature furnace is fired with Surface Combustion burners provided with Eclipse regulators and mixers, and low pressure gas.

Propane gas is used throughout, but in the tempering zone this is introduced to the burners at 25 lb. pressure which gives ample energy for the inspiration of the necessary 20 volumes of air for combustion. Very satisfactory regulation has been experienced from this arrangement and a wide range of turndown is possible.

The tempering zone is designed to operate up to 1300° F. Bright heat treatment has not been attempted, but good regulation of furnace atmosphere is attained. Sulphur is absent from the fuel.

Supervision and Operating Details. The over-all length of the furnace from the charging end to the discharge end is about 45 ft.

The leading operator loads the trays. He can set up half a dozen at one time, which are then carried forward automatically. This gives him time for attention to other duties



Each Item Is Quenched Separately and Carried up Out of the Oil by a Flight Conveyor, Pushed Into an Appropriate Stall, and Automatically Tilted Into the Drawing Furnace

about the machine before it is necessary to do more loading. He watches the temperature at the quenching end and inspects the quenched work. Samples of the quenched parts are taken every hour, or oftener, for hardness tests.

A helper watches the regulation of the tempering end and unloads the hoppers into which the tempered work is discharged. He also bags or otherwise loads the work after it has cooled. He submits, at regular intervals, samples of the finished work to the leading man for check. Samples are later rechecked by the inspector.

Operation is continuous through three shifts. This type of furnace necessarily gives the best regulation when it is in continuous operation. Stopping and starting make temperature control difficult because of the irregular heat consumption and saturating time, and require the passage of a dummy load to regulate matters. Therefore, once the furnace is started, it is run continuously 24 hr. a day until the supply of work on hand is exhausted.

A recording clock chart registers the time and duration of any interruptions that may occur in the routine.

The capacity of the furnace, approximately 1000 lb. per hr., is a variable depending upon the nature of the work and the weight and thickness of the parts. It may, in some instances, be considerably increased. The system of trays for carrying work through the furnace provides wide flexibility for different types of charge; either small parts or large parts, within certain limits, may be placed on them. The size and shape may vary greatly, but must of course be uniform for any one run. The parts are not subject to mechanical strain in passing through the furnace.

Conclusion. This furnace is installed by a firm which does nothing but commercial heat treating. The general and varied nature of the work handled makes it important that any new apparatus installed should be highly adaptable in nature rather than specialized. Yet, at the same time, it must be efficient. The furnace described in this article, although primarily intended for a particular job, was designed by the author with these needs in view, and can be readily converted to heat treat a wide variety of shapes and sizes.

At the date of this magazine, the furnace has been in operation for more than three months with very satisfactory results.

Work Leaving the Tempering Furnace Down an Inclined Roller Table. Handling parts of this peculiar shape is quite a problem, as they will neither slide nor roll along without getting tangled up

STATISTICAL ANALYSIS OF METALLURGICAL PROBLEMS

By Edward M. Schrock
Supervisor, Statistical Division
Jones & Laughlin Steel Corp.
Aliquippa, Pa.

YOU can never prove anything by statistics! At best, the use of statistics is merely the attempt to picture, in numbers, a condition that exists in fact. The statistics by themselves are empty and meaningless. It is only when we know the factors that they represent, the conditions under which they were obtained, the way they were handled, that they can assume meaning.

On the other hand, statistics never lie! It is only men that lie. Not that they do so intentionally; but because of their inability to weigh properly and evaluate the circumstances surrounding the statistics, they read in meanings that are not there, and read out meanings that are there.

Recent years have seen significant progress in the application of statistical methods to metallurgical industry. Notable in this respect is the work that has been done by PASSANO at American Rolling Mill Co., REAGAN at Edgewater Steel Co., CHANCELLOR at National Tube, CHIPMAN at M.I.T., WATERMAN at Youngstown Sheet & Tube, and NORRIS at Wheeling. Men such as FRY, DAEVES, PEARSON, DODGE, SHEWHART, and HAND have written at some length on the application of statistical methods in industry. We will therefore deal primarily with the *practical* development of a *workable* program for analysis of metallurgical problems.

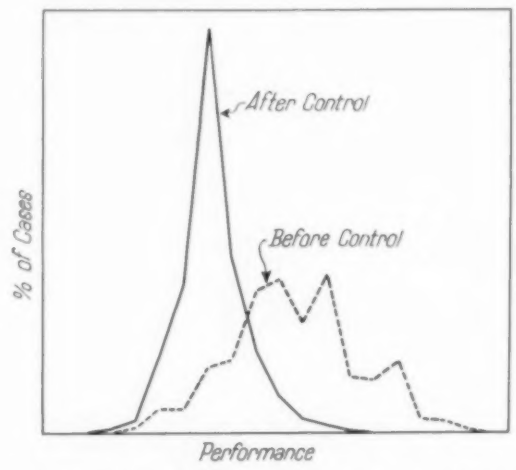
Statistical analysis is nothing if not "practical" and "workable". If that is true, we may well ask why industry has been so slow in adopting this method of approach to its metallurgical problems. It is our belief that this has been due essentially to the lack of emphasis on the savings that it can achieve. The future course of statistical work in industry will probably be largely determined by the extent to which management is convinced of the financial savings it can accomplish.

The saying "Truth will out" does not always apply. We sometimes fail completely to uncover it in the maze of complicating circumstances that surround it. Indeed, in spite of the progress made in the metallurgy of steel, it is a simple matter to name some 25 or 30 variable factors in the manufacturing process, the true significance of which is unknown. At best, our control is uncertain and rarely do we know the financial value of the normal fluctuations that occur in the manufacture of steel.

With this in view, we must develop our statistical program with the purpose of determining the importance of the variations that normally occur in practice in order that we may reduce scrap losses, increase yields, and

improve quality. In spite of the exactness with which parts are produced today, variations in the product do occur, although delicate instruments are sometimes necessary to measure these differences. Such variations may make the part in question unfit for its intended use. The essential purpose of our modern statistical approach is to determine when these variations that do occur are the natural result of chance influences and when they are the result of influential factors over which control can be exerted.

Among the potentialities of statistical analysis is the possibility of determining the extent of the inspection program necessary. Savings may be realized by carrying on a restricted program of inspection, limiting the number of samples tested to that adequate to give statistically reliable results. This is particularly valuable when the test is destructive.



Improved Uniformity of Performance With Establishment of Control. Dotted line represents period before control was established. Notice the decreased variability after control was obtained.

Another potentiality is the improvement of quality. Much of management's efforts in the past has been directed at reducing scrap losses and raising yields. While this is naturally one of the chief aims of any well-rounded statistical program, there are also subtle quality values involved. Thus, when we reject 5% of a heat for quality reasons, there is probably an additional portion of the heat which, while it passes inspection, does not achieve the high standards of quality we desire. If we find it necessary to reject only 2% of a heat, the possibility of there being additional material that is barely able to pass inspection is greatly reduced. On the other hand, the production of large quantities of material that barely meets minimum standards is almost certain to result in some actually defective material slipping by even the most careful inspection, and there is almost certain to be an eventual customer reaction.

In some cases we may aim at the improvement of quality through indirect approaches, as in the control of phosphorus in seamless tube steel. It is a well-established fact that low phosphorus is an important factor in the production of high quality tubes; it is further known that the equivalent lime charged in the basic open-hearth is an important factor in the control of phosphorus. Our first step, then, is to determine statistically the optimum equivalent lime charge that will give the most economical control of phosphorus. This should be immediately followed up by tabulations relating the phosphorus analysis of the steel with quality results in terms of rejected tubes and chipping costs. The first step is thus an investigation aimed at control measures which in themselves cannot be readily evaluated in terms of actual savings effected. Indirectly we bring about a quality improvement which can be evaluated.

Let no one minimize the importance of this latter step. If we are going to sell our program to management, we must show results. The most effective way to do this is to evaluate the results in terms of costs.

This brings us to a consideration of what I am inclined to feel is the crucial test of any metallurgical statistical program, and that is the lowering of manufacturing costs.

An Instrument to Lower Costs

We may be inclined to feel that this is outside the realm of metallurgy, thinking that the metallurgist is primarily concerned with the development and application of standards of quality. Plant management, while it must necessarily aim to satisfy the customer, is also vitally concerned with costs.

While it is true that many of our quality standards adopted to meet customers' requirements have resulted in increased operating costs, the opposite is frequently just as true. A good example of this is the matter of hot top insulation in the production of seamless tube steel. We experimented on one occasion with several different insulators. For practical reasons the field was finally limited to two. Tabulations comparing these two resulted in definitely establishing one to be superior. When used it resulted in a sounder steel internally

and consequently fewer inside seams in the finished tubes. The savings were calculated to be in excess of $13,000 annually.

Another example involved the use of mold coatings for the same steel. A certain mold coating came to us highly recommended, but experiments, evaluated by statistical analysis, found it without question to be inferior to the one we had been using. To have adopted it would have cost the Corporation over $398,000 annually in the form of higher chipping costs.

Here we have a direct appeal to both the metallurgist and management, as to quality and costs. A savings figure of $25,000 a year is certain to command more consideration than any report which is not interpreted in terms of costs.

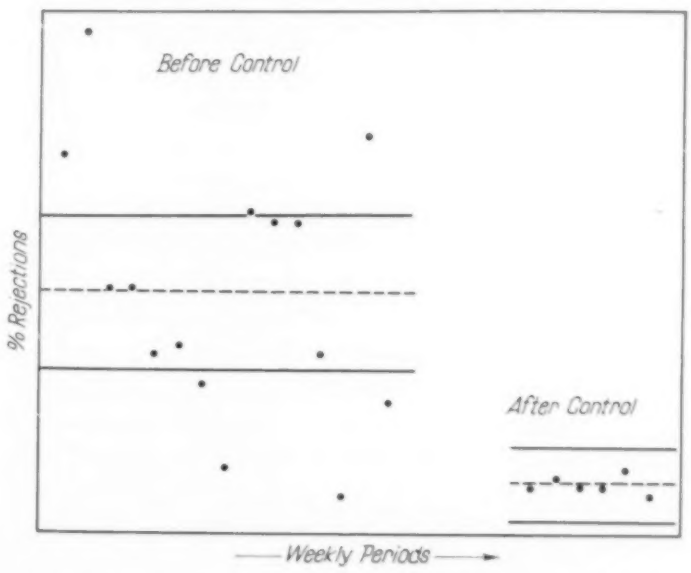
Statistical Techniques

We will not attempt to consider the general theory. There are many excellent texts and articles that cover the field. In the conditions under which we normally work, there are a great many factors operative at the same time. This requires a much different approach than when only one factor varies at a time. Let us consider, then, some of the more common techniques applicable to metallurgy.

Perhaps the earliest approach to this problem was that of using large masses of data based on the "law of large figures" which states that if a sufficient number of measurements are taken, the large number of secondary circumstances that exert an influence on an individual result will compensate themselves so that only the main factor will penetrate and demonstrate its importance. The obvious shortcoming in this method of attack lies in the difficulty of deciding just when our figures are large enough.

"Probability" is one of the most important modern concepts in the field of statistics. It is a well-known fact that no two items are ever identical in every respect. Suppose we have a large number of accurate measurements of the diameter of a machine-made part. If we arrange these results in order, count the number of identical values and plot number against value, we have a "frequency polygon". If we have measured enough parts, our results would tend to approach the normal curve representing the results we would obtain from a universe of data. Such a normal curve may also be constructed theoretically. The curves that we construct from limited volumes of data naturally vary from the normal curve, and certain inferences may be made as to the deviation of the actual polygon from the ideal curve, such as a peak off center, a double peak, a flat peak or a peak too sharp. The frequency polygon also offers an excellent method of illustrating improved performance after control of a process has been established. An example of this is shown in the diagram on the opposite page.

Another important analytical consideration is the tendency of the individual items in the distribution to vary from the average. It is commonly measured by the standard deviation (or "sigma unit") computed from a simple formula involving the fraction of the lot that is defective and the size of the sample. If we measure off along the base line of the normal curve three sigma units in each direction, we will have included over 99.7% of the total area or items represented. Stated in terms of chances, this means that there is only one chance out of 370 that any individual item will fall outside these limits. This chance is so small that the "three-sigma limit" is commonly accepted as representing the maximum variation that can occur due to chance alone. If now we plot the per cent defectives for a given period of time, and



Rejections Before and After Establishment of Control. The dotted lines represent average rejections. The solid lines are the upper and lower "three-sigma limits". It will be noted on the left side of the chart that before control was established many of the weekly rejection figures fell beyond the limits that could be due to chance alone. In addition to establishing control, as shown at bottom right, there has been marked decrease in number of rejections

several dots fall outside these three-sigma limits, it is positive evidence of the existence of a causative factor. (See the second diagram, page 155.)

By the use of control charts, the percentages of defective material, averages, standard deviations, and shape of frequency polygon, we can reveal whether lack of control exists in any one or more of these aspects. If all of these aspects show lack of control, we may well suspect the existence of a major causative factor.

An account of the operations of a statistical division, attached to the metallurgical department, that has enabled a large steel producer to determine which of alternative methods is really best, to pick out the variables in a process that must be controlled in order to get a more uniform product, and to revise the inspection systems so as to catch a larger proportion of below-par items

"Correlation" is another important statistical concept. The old idea of quantitative measurements was based only upon magnitude. Thus, we have a number of observations, which, averaged together, produce the true magnitude of the quality involved. The modern view sees these measurements as constituting a distribution of the quality.

The essential purpose of all these techniques is to get away from the old idea of inspection as merely a method to screen out defective parts, and to make practical use of inspection results to set up new standards for more effective production.

Preparation of Reports

In view of the fact that interpretation of the written word is such a difficult proposition, it is not sufficient that we write our reports so that they can be understood; they must be so clearly presented that they cannot be misunderstood. To insure this result it is important that they be written in the language of the intended readers, namely metallurgists and managers. We must avoid, therefore, the use of statistical terms or reference to techniques that are not common knowledge.

Perhaps one of the most effective approaches is to emphasize the "consistency and regularity of data". If for several successive months we find the same relationship in the data in connection with some problem, we may place more confidence in these figures than the figures for an even longer time when presented in one sum total. One or two erratic months might throw an over-all figure out of line, but when analyzed month by month, the relationship would be evident.

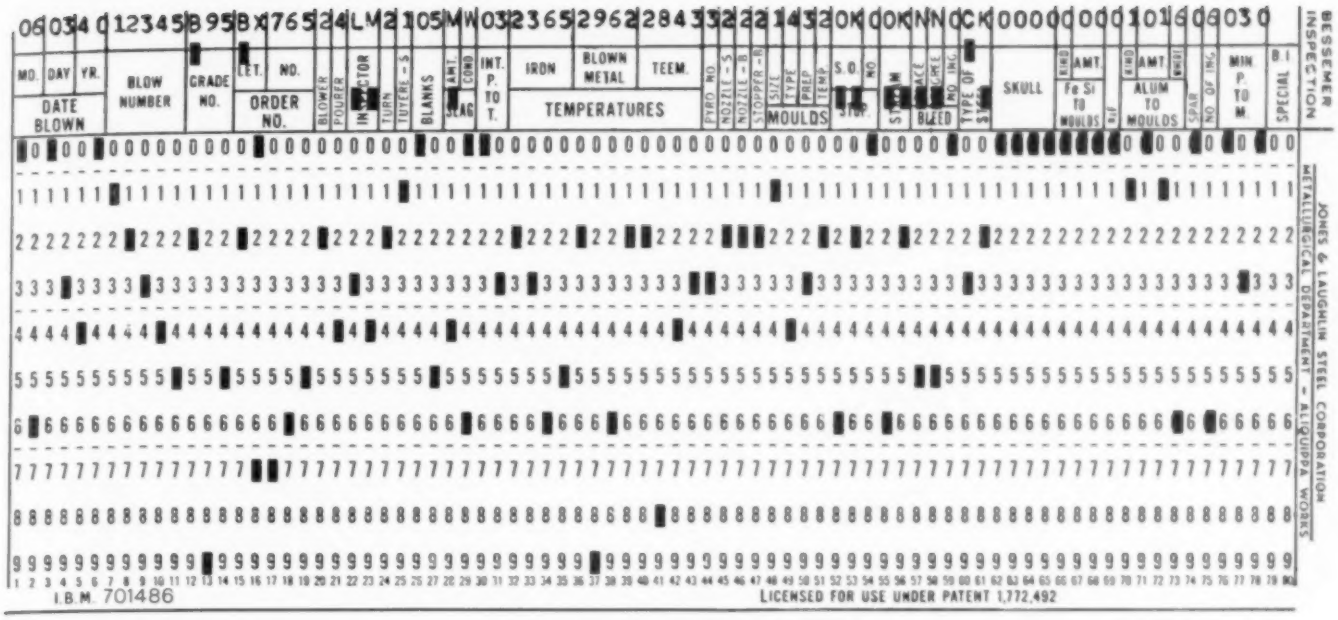
One problem of this type that we encountered involved the comparison of two possible operating variations in the bessemer process. That is, we could use either method *A* or method *B*. Apparently they were equally effective. A statistical analysis covering several types of products over a period of five months showed method *A* to be definitely superior. Ten out of 12 possible points of comparison favored method *A*. The two that favored *B* did so by very narrow margins, and what happened was that the tonnages involved in those two cases were so limited that other influential factors were not neutralized and consequently upset the results. The consistency and regularity of the major portion of the data, however, was such as to indicate the existence of an important causative factor. The adoption of method *A*, incidentally, has brought about an annual savings to the Corporation of approximately $40,000.

Organization

Metallurgical — The creation of a statistical division will likely involve a number of changes in the inspection forms, production forms, and the reorganization of inspection programs.

In view of this, it is highly desirable that the investigation, inspection, and chemical divisions come under one supervisory head, with the statistical division responsible to this head. Such an arrangement will permit a maximum number of readjustments for effective service with a minimum amount of red tape or interdepartmental friction.

Personnel — The type of leadership needed to carry on successfully a metallurgical program of statistical analysis requires a high degree of open mindedness. This does not imply that there should be any lack of convictions,



A Typical Tabulating Card

but there must be a willingness to accept new ideas that are contrary to established beliefs. There can be no sacred cows!

The actual size of the staff will depend upon the size of the plant and how extensive a program is desired. We will consider some of the additional help that would be required for a program similar to our own.

A tabulating machine operator will be necessary. A code clerk will be required to prepare inspection and operating reports for the card punching machine operator. One or two card punching machine operators will be required according to the volume of data handled. This will complete the office staff. In addition, a mill staff will likely be needed. At the present time we have four men located in Jones & Laughlin's steel works whose task it is to gather information from a variety of operating and inspection records (actually 11 in number) and consolidate them on only four different forms from which cards similar to the one on this page are punched.

Equipment — It is true that a statistical program can be carried on without the use of tabulating machines. In a plant the size of ours, however, the scope of the work would be too limited without machines. Data covering several years may be tabulated in a few hours mechanically, whereas a manual tabulation would require many days.

The number and type of modern machines needed will also depend upon the size of the plant and scope of the program planned. The program which we have developed utilizes 20 different card forms, on which the information is printed across the top as well as punched in the body of the card. (A typical one is shown on this page.) This not only affords the machine operator ready interpretation of the information punched, but also makes it useful for reference purposes when on file.

Five machines will be needed. The alphabetic printing punch punches the card and prints the information across the top of the card. The card counting sorter sorts the punched cards into pockets according to the hole punched in any pre-selected column; it also counts the cards going into each pocket at the same time that it sorts them. Since the quality factor we are studying is usually recorded on one card and the results in terms of rejections, scrap, or yield on another card, a machine called the collator may be used to match up the two decks of cards involved. The reproducing punch is used to punch, on a blank set of cards, some information from one deck of cards, and some information from another deck of cards. Finally, the alphabetical accounting machine will perform a variety of operations according to the manner in which its control board is wired; essentially, it is used to tabulate cards and print the totals according to the controls established.

All these machines will handle from about 100 to 400 cards a minute according to the operation being performed. The rental is considerable; on the other hand, they make it possible to save several times the amount invested in the entire statistical organization.

Program

Statistical investigations should be conducted along three general lines:

1. *Mill Operating Factors* — In the manufacturing processes, there are many variable factors whose true significance is not known. In this field lies the greatest promise for developing useful facts, and the variables over which we can exert some control.

2. *Personnel* — Men vary considerably in both their ability and their performance as related to their ability. Responsible operators, such as melters, heaters, and rollers, should be studied wherever possible in relation to the quality of their products. This field should receive somewhat less attention than mill operating factors, for control is much less exacting, and the improvement we can make is less pronounced.

3. *Extraneous Factors* — This would include such things as weather, seasons and months, turns, and day of week. Inasmuch as little or no control can be exerted in this field, these factors would receive the least attention. However, they cannot be ignored.

Reports issued would fall into three general classifications:

1. *Periodic Reports* — These for the most part would consists of monthly or quarterly reports on factors of established significance. They would serve to summarize current practice and re-emphasize the importance of factors previously established as significant.

2. *Requested Reports* — Prepared on subjects of current interest. If the results are sufficiently significant they may become subjects for periodic reports.

3. *Reports Originating Within the Statistical Division* — Factors of suspected significance should be investigated and reported upon from time to time.

In addition to the statistical methods which we have already discussed, I would like to add two additional types of procedure that may be employed:

1. *Results Based Upon Selected Operating Data* — The data selected will be drawn from cases where several operating variables of known importance are identical. Thus, factors of known influence may be eliminated beyond doubt. Much less data are needed here than when we merely depend upon large masses of data with the assumption that influential factors, not controlled, will cancel themselves out.

2. *Data From Heats With Selected Results* — Here we will select only those heats whose results have shown excellent quality. We will assume that the operating conditions that prevailed must have been acceptable. By determining what variations *did* occur in the operating conditions for a number of such good heats, we may establish acceptable limits of variation for each operating factor.

We have attempted to describe what we feel constitutes a sound program for statistical analysis of metallurgical problems. We do not mean to imply that we have achieved in *our* program all these things, nor do we infer that any company can necessarily achieve all of them. We are, however, convinced that through the expanding use of programs of this type, metallurgical progress will be greatly expedited and thousands, yes, even millions of dollars saved in operating costs.

Statistical Analysis Aids in Determining the Correct Tolerances, and Percentage of Pieces That Need to Be Inspected. Photo courtesy of Timken Roller Bearing Co.

REVIEWS OF IMPORTANT BOOKS

Alloy Steels

FUNCTIONS OF THE ALLOYING ELEMENTS IN STEEL, by EDGAR C. BAIN. 312 pages, 6x9 in., 186 illustrations. The American Society for Metals, Cleveland. Price $4.00.

Reviewed by FEDERICO GIOLITTI

A specialist, such as the present reviewer, who has devoted the greatest part of his activity for nearly 40 years to the practical applications of technical knowledge — like that concerning special steels — must necessarily be more or less acquainted with most viewpoints, opinions and theories relating to that field, and has very seldom the agreeable surprise of finding something really new in the literature devoted to that branch of knowledge.

The writer had such an agreeable surprise when reading for the first time this book by Dr. EDGAR C. BAIN, the eminent American metallurgist, who is now high in the technical councils of the U. S. Steel Corp. The new, simple and complete presentation of the typical roles of alloying elements in steel, and the classification of these influences in well-defined and clearly described categories, prompts me to prophesy that this book will act as a key to the logical interpretation of many extensive studies or research programs, as well as of valuable treatises on alloy steels already in print or yet to be printed. In these treatises, unfortunately, the information is presented more or less as would be done in catalogs — uncritically, and without many clues as to which statements are the really important ones.

In other words, from a didactic point of view — the viewpoint of one who tries to transmit information — this book is the first, to my knowledge, to find a logical place between the general physico-chemical study of metals and the detailed practical study of the vast series of alloy steels produced by modern metallurgy in ever-increasing numbers and forms.

In addition to its original general plan, Dr. BAIN's volume contains many unique and interesting features, especially interesting from a teacher's viewpoint, that should not be overlooked in a complete analysis of the book. Unfortunately, on account of the abundance of matter about alloy steels condensed in a comparatively small space, such an analysis would greatly exceed the limits allowed to a regular review. I must, therefore, confine my remarks to a few particular points:

In the very short introductory chapter stating the "Viewpoint and Scope", the author insists especially on two points, forming the essential basis of the didactic system adopted throughout the book: The first point concerns the necessity of basing the systematic study of alloy steels on continuous and close comparisons to plain carbon steels, while the second refers to the fundamental importance of finding out *how* the alloying elements enhance the valuable properties of ordinary carbon steel. This last remark is more completely developed in the third chapter on the "Alloying Elements in Unhardened Steels" where the influence of the various common alloying elements, studied one at a time as they affect the microstructure and physical properties of the basic carbon steel, is shown to be surprisingly small in the annealed condition.

The second chapter ("Fundamental Characteristics of Steels") contains a clear summary of the essential facts concerning *carbon* steels, with special reference to their structural interpretation. This study is basic to the author's plan of presentation. The systematic study of the conditions of transformation of austenite, different modes of carbide dispersion (various spheroidal and lamellar structures), hardenability, and grain size supply the basis for the concluding part of the chapter, where Dr. BAIN, in an excellent synthesis, defines clearly the fields of application of carbon steels and those of alloy steels from a practical point of view, showing the limits in which real improvements of given properties of carbon steels may be expected by adding alloying elements.

Chapter IV ("Effects of Alloying Elements

in Forming Austenite") discusses the processes of diffusion of dissolved carbon and other elements in austenite at high temperatures. Both theoretical and practical examples and arguments are marshalled to emphasize the fundamental importance of appropriate heating cycles for hardening. Proper attention is also given to the practical effects of inclusions and grain growth.

The fifth chapter ("Effects of the Elements in Hardening Steel") is certainly the most important, and clearly shows the practical usefulness of the didactic plan adopted by the author. By an extension of the already quoted preliminary conclusions of the second chapter, Dr. BAIN reaches a more complete and clearer definition of the general principles which limit the field of application of alloy steels, and which determine when and to what extent their use provides decided advantages in place of heat treated carbon steels.

Every part of this chapter would deserve a detailed analysis, but only a few points may be made in the allotted space.

In the discussion of hardenability, intensity of hardening and grain size in alloy steels, many original viewpoints are developed, showing clearly the general principles for a rational choice of the alloy steels best suited for given purposes. Incidentally, the author leads to the conclusion, of great practical importance, that alloy steels are frequently no better than properly treated carbon steels, while, in special cases, the results obtained with plain carbon steels, properly treated, may even be superior to those obtained with alloys less appropriately treated.

Conclusions of similar importance are reached from a discussion of the degree of homogeneity of austenite as it influences hardenability, and the effects of heating temperatures before hardening.

The sixth and last chapter, almost as extensive as the fifth, treats of the "Effects of Alloying Elements in Tempering" and is planned along the same lines as its predecessors. The nature of the changes in hardened plain carbon steel is first set forth, and then it is shown how the presence of specific alloy elements, either in solution in the ferrite, or in a special carbide, or distributed between these two forms, modifies the essential reactions, and therefore the resulting mechanical properties.

In a short recapitulation concluding the book, Dr. BAIN states that his "series of discussions has shown that alloying elements accomplish improvements in steel properties through comparatively few fundamental influences". No statement could better indicate how completely the author has attained his aim.

A Heat Treatable Bronze

ALUMINUM BRONZE. 150 pages, 6x8½ in.; 83 illustrations. Published for promotional purposes by Copper Development Asso., Millbank, London, England.

Reviewed by W. W. EDENS

It is indeed a pleasure to be able to pick up a book which has between its covers such a wealth of information about one of the important non-ferrous alloys. This one deals with the production and fabrication of aluminum bronze, not only as castings, but also as wrought material. It is profusely illustrated and contains numerous diagrams and tables showing various physical properties as well as other pertinent data. The book begins with the general properties of the alloy, including a discussion of the equilibrium diagram of the binary copper-aluminum alloys. From this fundamental beginning, consideration is given to the alpha type or cold working aluminum bronzes, aluminum bronzes for hot working, aluminum bronzes for casting, the corrosion resistance of aluminum bronzes, their production and fabrication, and the industrial applications.

The use of alloying additions such as lead, manganese, iron, nickel, and silicon is considered in both the hot worked and the casting alloys. The authors show a decided preference to iron and nickel in amounts ranging up to 5%, and manganese in amounts ranging up to approximately 1%. They recommend the use of iron particularly (and nickel to some extent) as a grain refining and stabilizing addition resulting in improved physical properties. Manganese additions in amounts of about 0.2 or 0.3% are recommended as being extremely useful for deoxidation, and quantities up to about 1% as a strengthening and hardening element.

Considerable attention is given to the corrosion resistance of the aluminum bronzes. Numerical data show the rate of corrosion of various types in various mediums. This statement is made: "The aluminum bronzes are renowned for their good performance in a considerable number of industrial applications where a wide range of corrosive materials, both gaseous, liquid and solid, is encountered."

The book also contains considerable information about the heat treatment of aluminum bronzes. Microstructural changes upon heat treatment are clearly shown. Relatively large increases in strength and hardness can be achieved by means of a quench and draw. Particularly significant are increases in the yield strength from 24,500 to 31,500 psi. as-cast to about 40,000 psi. after heat treatment — this on an alloy containing 88% copper, 9% aluminum, and 3% iron.

Of particular interest is a paragraph comparing aluminum bronze and manganese bronze castings, in which the following statement is made: "The wear and abrasion resistant characteristics of the aluminum bronzes are outstanding, and for products such as worm wheels and gears the alloys are much superior not only to manganese bronze but also to steels; in this respect, the advantage over the brasses is altogether greater than would be anticipated from a mere comparison of hardness values."

If there is any single outstanding feature of this book, it is that all the information given is of a very practical and commercial nature. It is also well amplified and fortified with a complete bibliography of 211 references, and as such can really be considered as a handbook on aluminum bronze.

Jewelry and Dental Scrap

REFINING PRECIOUS METAL WASTES; Gold, Silver, Platinum Metals; A Handbook for the Jeweler, Dentist and Small Refiner by Miss C. M. Hoke. 362 pages, 6x9 in. Metallurgical Publishing Co., 123 William St., New York. Price $5.00.

Reviewed by JOHN L. CHRISTIE

This book is the result of 24 years of experience in teaching jewelers and others how to refine their precious metal wastes. It assumes complete inexperience on the part of the reader. It describes in minute detail the procedures to be followed in the reclamation and refining of various combinations of precious metals and the separation of the various metals from each other and from the base metal and various types of dirt which may be present.

The book does not cover the refining of virgin ore or crude metal; it does not cover assaying; it concerns itself only with secondary refining, that is, the refining of precious metals that have already been in use and are now waiting to be returned to further employment in arts and industry.

While the book describes fully the processes used by such large plants as the United States Mint, its main concern is with the reclamation of wastes from the small manufacturing plant — the jewelry factory of from one to 100 men, and the average dental laboratory of one to six, and it describes the recovery of gold, silver, and platinum group metals from the waste that such plants produce. Two chapters are given over to a description of the processes used by some of the professional refiners, not with the idea that the small operator will use the methods but rather that he may be interested in them.

The book is written for the man without a knowledge of chemistry. The method of presentation is to begin with the simplest cases and from them to proceed step by step to the more complex. The purpose of the book is to show the precious metal worker not only *how* to refine his scrap, but also *what* to refine and *when* to refine it.

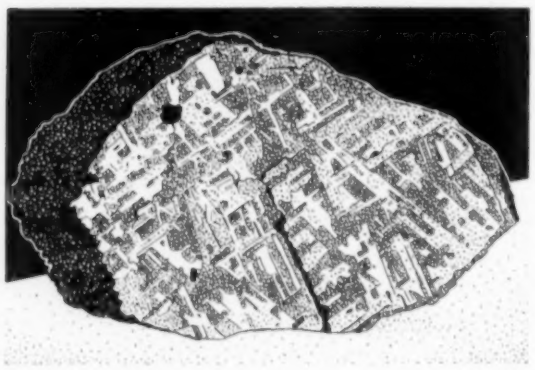
While the author in several places recommends that certain products be sent to a commercial or professional refinery and while she presents the case for and against the small shop's doing its own refining, it appears to the reviewer that, as might be expected from the business interests of the author, more weight is given to the *pro* side of the question.

The subject matter is presented in detail so that it can be followed as one works, like a cook book. The assayer and analytical chemist will recognize his own methods of separation in the wet procedures described. In the case of the platinum group metals simple chemical reactions do not effect complete separation; considerable skill and judgment must be used in making these separations either in the analytical laboratory or in the small refining department. Standards of fineness and purity to be met in order to meet the demands of consumers are high. Too much emphasis cannot be given to the necessity for constant check and control on the fineness of the various precipitates in the refining process, and it may be presumed that most frequently the result of small-scale refining would be acceptable only for reuse in the plant that produced the original scrap.

The book contains a chapter on platinum melting which is an excellent discussion of the subject. The chapter on "Hazards and Safety" is authoritative. A brief summary is included covering the laws and regulations pertaining

to the handling and marketing of precious metals and their alloys. Finally, the book contains an excellent bibliography which is quite up to date, some of the references being as late as the year 1940.

Miss HOKE is an authority on her subject and her book deserves a place on the desk of every worker in precious metals.



Metallography

PRACTICAL MICROSCOPICAL METALLOGRAPHY, by RICHARD H. GREAVES and HAROLD WRIGHTON. Third Edition, 1940, 272 pages, 6¼x9¼ in., 331 illustrations. Printed in England; sold by D. Van Nostrand Co., New York. Price $6.50.

Reviewed by ERNEST E. THUM

This revised and enlarged edition of an admirable textbook nears perfection in its aim: To tell how to make good micrographs, to exhibit and interpret representative structures of important metals and alloys, and to show how these structures and the associated mechanical properties change with manipulation and heat treatment. The first 100 pages of the text describe the preparation of specimens (hand polishing on stationary plates is recommended) and the equipment and methods for examining and photographing the structures. While the principal aim is to instruct the beginner or advanced student (witness the tables of difficulties, causes and remedies, and the frequent paragraphs headed "Practical Notes"), the precautions and manipulations necessary to extract the last iota of quality from the available lens system are set forth as clearly as they have been in J. R. VILELLA's book on "Metallographic Technique for Steel".

The authors distinguish between low power micrographs, say at 10 to 15 diameters, and macrographs meaning life-size or small scale views. Either group requires its own illumination and lens systems, quite different from those used by the metallurgical microscope. This portion of the book is to be especially recommended to Americans, for it is the reviewer's impression that the quality of the average illustration submitted to him goes down with the magnification. This book not only tells what equipment to use and how to assemble it, but how to test it for its sufficiency.

The second 100 pages of text contain a clear account of the metallography of steel and cast iron, and about 175 of the finest micrographs you ever have seen—in number and choice comprising a condensed metallographic atlas. The engravings have been made through a somewhat finer screen than used in METAL PROGRESS halftones, and are printed on heavy, dull-finished white sheets, tipped into the book. Here again the text has been carefully worked out to tell the facts simply, so the non-expert can understand and apply them, but the average student would probably be driven to despair when attempting to match the quality of the micrographs. 1930 nomenclature has been retained to describe the structures of heat treated steel, but clear distinction is made between the "sorbitic pearlite" which transforms direct from austenite, and the "sorbite" in tempered steel which is fine granular cementite in a ferrite groundmass.

The final portion of the book carries a similar treatment through the field of non-ferrous alloys. Here, it seems to the reviewer, is the best chance for future improvement in the book. The text could be expanded to cover other alloys. Likewise the micros suffer in comparison with those given earlier, although there are some magnificent ones borrowed from L. NORTHCOTT's works on copper and zinc alloys.

NOTE AS TO COST: The price of $6.50 will choke off almost completely the market where this book will do the most good—namely students in American technical colleges. At present rate of exchange this amounts to £1 15s.; it may be doubted whether many English students could afford that sum either — in fact it may even be doubted whether that price is quoted in England. This book could actually be reproduced (type set, e n g r a v i n g s made, printed and bound) in Cleveland for $1.40 each in 2000 lots. Allow 200% for promotion, overhead and unsold books and the cost comes to $4.20. Suppose the authors get 75¢ royalty, and we still total only $4.95 (say $5.00 in round numbers) as a fair selling price.

Other Books Received

DESIGN SPECIFICATIONS FOR BRIDGES AND STRUCTURES OF ALUMINUM ALLOY 27S-T; prepared for Aluminum Co. of America by LEON S. MOISSEIFF. The form and methods of the book parallel those of the American Railway Engineering Association's specifications for steel railway bridges, as modified and interpreted in the light of extensive experimentation with model and full scale structural aluminum members and assemblages. Mr. MOISSEIFF, a well-known consulting engineer in bridge design, believes that the correct use of these specifications will provide an aluminum bridge having the same factors of safety for strength and stability as those prevailing in modern steel bridges.

COMMODITIES IN INDUSTRY is a large book of 720 8½x11-in. pages published by Commodity Research Bureau, 82 Beaver St., New York, at $7.50. It will contain much ammunition for those who like to worry about the United States' self-sufficiency in all kinds of raw materials. General descriptive information on production, and statistics about American production and imports for the last decade, are given for 75 commodities ranging from alcohol to zinc. Encouraging, for instance, is the information that Cuban and Brazilian deposits could readily provide us with one third of the million tons of manganese ore required for our steel industry in 1940.

THE MINERAL MAP OF EUROPE is of more limited scope, not only geographically but textually. Compiled by THERON WASSON, chief geologist of The Pure Oil Co., Chicago, for private circulation, it shows graphically the European mines and oil fields, together with the proportion of world output produced therein. It shows, for instance, that one of the most serious of the results of the French defeat is the loss of her aluminum ore (bauxite) drawn heavily upon by the British industry. France produces 25% of the world's bauxite, Hungary 13%, Yugoslavia 11% and Italy 10%. Mr. Hitler will never be starved for the wherewith to make aluminum!

VERBATIM RECORD of the Proceedings of the Temporary National Economic Committee has been published by The Bureau of National Affairs in Washington, at $5 per volume (each containing about 650 8x11-in. pages). Volume 9 contains most of the testimony about the steel industry, principally about the iron ore trade and the pricing system for steel products — not only the base prices and extras, but the method of handling freight charges known as "Pittsburgh plus". Volume 9 is more valuable for its testimony about the copper mining, smelting and fabricating industry and its sales policies.

Germans Turn to

MANGANESE & SILICON

for Alloying in Steel

Abstracts from reviews in *The Engineer*, August 1939 and June 1940

SINCE there has been a shortage in Germany of the favorite alloying elements (especially of nickel and molybdenum, and even of chromium and vanadium) metallurgists and researchers in that country have turned to the utilization of silicon and manganese. *The Metallurgist* for August 1939 and June 1940 (supplement to *The Engineer*, London) has summarized several German articles about these steels, some of which are said to be the result of five years of experience in production and use.

Their silico-manganese high tensile structural steels are usually lower in carbon and higher in silicon than the ones used to a limited extent in Great Britain. One problem has been the correct normalizing or finishing temperature. It is generally stated that silicon increases the A_3 critical temperature forming a "gamma loop" closing somewhere between 2.0 and 2.5% silicon in carbon-free iron, and it may be that this is associated with the fact that heat treating temperatures are generally higher in the silicon steels. WILHELM and RESCHKA, in one of the German papers cited, present some dilatometer curves that may be interpreted as showing that a uniform solid solution (austenite) is not achieved until the temperature has risen to 1800° F. for a steel containing 0.20% carbon, 1.10% silicon and 0.50% manganese. A normalizing temperature 35° below this caused unmistakable loss in the figure for yield point.

This is no new observation. It has long been known that the silico-manganese spring steels require a specially high hardening temperature. Stainless steels high in silicon fail to respond to the standard heat treatment applied to those of the normal composition on account of the raising of Ac_3 by silicon and require an exceptionally high hardening temperature. F. BONSMANN has recorded that cast silicon steels attain their best mechanical properties when annealed at a temperature 100 to 150° C. higher than plain carbon steels.

Aging after overstrain is found to affect unfavorably the above-mentioned types of silicon steels as well as the manganese steels where the content of manganese and silicon is reversed. Both types, properly normalized, then reduced 10% by cold rolling, and "aged" 1 hr. at 500° F., lost at least half their notched bar impact strength when tested at room temperature. Maximum toughness of both steels as rolled, as normalized, or as aged, was had when the testing temperature was about 200° F.

Carburizing Steels

In former years the standard high tensile carburizing steel in Germany was designated ECMo 100 and contained about 0.20% carbon, silicon less than 0.35%, 1% manganese, 1.25% chromium and 0.25% molybdenum. It could be used after heat treatment with tensile strength in the range 150,000 to 200,000 psi. Several published articles now indicate that manganese-chromium steels are satisfactory; it is also claimed that as compared with chromium-molybdenum steels they are rather less affected by differences in cross-section.

If the parts are relatively small (less than ⅜ in.), the necessary core strength is had by raising the carbon. For greater cross-sections, up to 2½ in. square, the addition of an alloy is necessary to attain the requisite core strength. An increase in manganese content alone is not advisable since the desired strength is only reached with the relatively high manganese content of 2.2%, which makes the carburized layer susceptible to overheating on hardening; such steels are difficult to manufacture free of silicate inclusions. Moreover, the ductility of the manganese-rich steel in the hardened condition is only moderate. It is therefore desirable to limit the manganese content to about 1.5% and to raise the hardenability and improve the properties of the core by the addition of silicon, vanadium, or chromium.

Manganese-silicon steels with 1.4% of silicon are unsuitable in parts wherein the core is severely stressed, on account of their lower toughness, and their use is limited to parts mainly subject to wear. Increase in core strength by 0.2% vanadium was insufficient. With higher vanadium the formation of difficultly soluble carbide diminished the maximum hardness of the case. The manganese-chromium steels were more suitable and gave properties somewhat similar to those of the chromium-molybdenum steels, ECMo 100. Carbon must be carefully minimized, else the ductility and impact suffer. A successful steel contains 0.20% carbon, 0.50% silicon, 2.0% manganese and 0.9% chromium. After oil hardening from 1525° F., test pieces cut from a 2½-in. bar gave 140,000 psi. yield, 185,000 psi. ultimate, 8.3% elongation, 35% reduction of area and 6.7 m-kg. per sq.cm. in Mesnager impact test.

Oil Hardening Steels

The influence of manganese content on the effectiveness of a hardening and tempering treatment applied to carbon steels is well known. In the range of approximately 1 to 2% it should be regarded as a valuable alloying element and there is great scope for steels of this composition. In the manganese steels the ratio of yield point to maximum load improves with increasing manganese. By raising the manganese limit, high tensile strength can be obtained in material of greater cross-section, with satisfactory yield point and no serious reduction in ductility. The importance of the high manganese carbon steels was recognized in Germany during 1914-1918, and their importance is now being reaffirmed for economic reasons. H. Kallen and F. Meyer (in *Krupp's Technical Bulletin)* present a summary of a large number of tests on manganese steels heat treated in heavy sections.

In the plain manganese steels the carbon is decreased from 0.45% to 0.30% and the manganese increased from 0.80% to 1.50% as the forgings increase from 2 in. up to 6 in. in diameter. Test pieces taken from larger pieces will show up to 110,000 psi. ultimate, 25% elongation in 5 diameters and 60% reduction of area.

For turbine and compressor shafts 4 to 10 in. in diameter the steel maker would add about 1% silicon to the low carbon, high manganese steel mentioned above. Such a steel hardens about as deeply and is less readily softened by tempering. In such large pieces the representative properties are 65,000 psi. yield, 100,000 psi. ultimate, 25% elongation, 60% reduction of area, and 9 m-kg. per sq.cm. impact (specimens 10x10x55 mm., notched 2 mm. diameter, 3 mm. deep). Such steels really approximate spring steel compositions, but with the somewhat lower carbon and the higher tempering temperatures (950 to 1100° F.) they have proved serviceable for various constructional purposes.

(Continued on page 192)

CRITICAL POINTS

By the Editor

TO ATLANTIC CITY, and found the meetings of the American Society for Testing Materials rich in organized programs on accurate chemical analysis — the tools and methods of analytical chemistry, micro-chemistry and spectrography. Little of this was preprinted and doubtless left a rather incomplete and confused picture in the minds of tardy listeners addicted to those late risings and leisurely luncheons the locale encourages. Spectrography in industry is used for three main purposes: Quick qualitative analyses, quick quantitative analyses of minor constituents, accurate determinations of 0.25% down to "traces". It was repeatedly emphasized that the analysis is no more accurate than the accuracy with which the "standard" basic or comparison sample has been formulated. . . . . Steel metallurgy has already profited enormously from the development of quick and convenient analytical methods. For instance, slag control in the openhearth requires a fast chemical method for FeO; it can now be done in 10 min. Carbon can be estimated in the metal in a few seconds by the electrical or magnetic properties of cast pencils (although final checks on this most important alloying element take 15 min. in a combustion train and the furnaces making alloy grade steels are usually held for the chemical report before going ahead). Certain alloying metals in pig iron and steel can be determined spectrographically and reported back in 6 min. when the works and laboratory are adequately tooled-up. Spectrographers would be doing metallurgical researchers a further service by devising methods for gaseous elements in metals, to replace the slow and unusually difficult chemical and physical methods. This last request is not new; it was suggested by PARRY some 60 years ago.

fast and accurate analyses

CLINICS were held at this same A.S.T.M. meeting on commonly used tests — their fundamental meanings and correct interpretations. The tension test was given especial attention, and emerged from the examination none too jauntily, having been discovered to show, not tensile strength, but most frequently the *shear* strength. The consensus was that, in addition to a certain load-carrying capacity, metals in service require ductility and toughness, that is to say, the ability to resist the formation and spread of cracks, either at corners or holes under more or less quiescent loads, at cracks or scratches under alternating loads, or anywhere under high velocity impacts. High ductility in the above meanings is usually (but not too correctly, it appears) associated with good values for elongation and reduction of area in the ordinary tension test. In HORACE GILLETT's opinion the ductility actually needed is that early plastic movement around stress raisers to redistribute more equally the stress, the rapid strengthening of these regions by cold work to prevent further yield, and the permanence of this new condition. Seemingly, if information about these things is to be had from a tension test it will come from its very early stages, now neglected as being even prior to the time the piece acts "in a purely elastic manner". . . . . Frequent mention was made of the cohesive strength, not the atomic stick-um but the strength under pure tension of the assemblage of crystals forming the metal. As pointed out by

ductility, toughness, propagation of cracks

Robert Rose, when discussing toughness of toolsteel in the April issue, the failure of a metal in a tension test is by necking and shear if its cohesive strength is more than double its shear strength. If the cohesive strength is less than double its shear strength a brittle break with no contraction in area results. This is more than an academic problem for sometimes "ductile" metals break in service with no "ductility" when they are loaded in such a way that shear movements are forcibly prevented. . . . . This situation is approached by Maxwell Gensamer in his determinations of static crack strength as reported in these pages last month, and discussed further in the correspondence pages in this issue. He produces a sharp and deep notch in the specimen, and when this is pulled the remaining area is thrown into something like "tri-axial tension" — that is to say, there is little chance for the load-carrying area to neck down by shear, for it is locked all around by a rigid surface ring of practically unstressed metal. Not being able to shift by shear, the eventual failure is by "splitting". High static crack strength, in this sense, is obviously desirable, and the ordinary tension test tells little or nothing about it. It should be remembered, however, that a shallow crack at the surface, even of equal sharpness, will not have the same effect as deep or internal cracks, for the presence of rigid surroundings is required for "brittle" breaks in "ductile" metals, rather than the presence of stress raisers.

TO Washington, Pa., to inspect operations at Jessop Steel Co., specialists since 1901 in plates, sheet and strip of toolsteel quality, and found myself among 😊 members occupying positions ranging up to President R. Edson Emery. With him and Works Manager Harry Wilson, Jr., discussed the business conditions which appear to set an economical limit on the size of toolsteel plants. While it is true that considerable variation exists, mill to mill, as to equipment and products, the nature of the operating unit usually does not differ greatly from Jessop's at Washington — two or three electric furnaces of 3 to 10 tons capacity, two or three heavy hammers for breaking down the ingots, and two to four hand-operated rolling mills for bars or flats. This seems to be substantially true even when several plants are consolidated in one organization, or when a large corporation has a toolsteel department. Americans order their toolsteels and fine steels in such small lots and to such an infinite variety of size, shape and analysis that utmost flexibility of production is required, and this is a feature of the modest-sized operating unit. Promptitude of delivery is also necessary, for inventories of finished steel at 50¢ to $1 per lb. cost the steel mill and its warehouses a lot of money.

diversity of toolsteels favors small organizations

T. S. Fitch showed me Jessop's division for making composite steels, of which he is manager. His firm has acquired P. A. E. Armstrong's method and the equipment formerly installed at Latrobe Electric Steel Co. (and described by Leonard Grimshaw in Metal Progress in May 1937). Essentially the process is to deposit 0.010 to 0.015 in. of electrolytic iron on the cleaned oxide-free contacting surfaces, assemble them into sandwiches, weld around the edges, heat and roll to finished size. The plating tanks can take heavy slabs which on assembly can be rolled into plates as large as, say, ¾ in. thick by 300 in. long by 150 in. wide. Carbon steel, stainless clad, in such large sizes has been fabricated into much chemical equipment and into conduits for reclamation projects and flood control dams. Such processes for stretching out a short supply of chromium or other strategic metals may be quite important in an emergency. Variously shaped composites of plain steel with high speed and other toolsteels are also manufactured in considerable variety of sizes and shapes. They prove not only economical in hack saws and wood cutting tools, but also possess a desirable combination of cutting hardness and resistance to shock and abuse. Fitch said there seems to be no limitation as to the kind of steels used for either insert or backing material.

electrolytic iron film welds metal composites

WAS TOLD that the story about Westinghouse's tool hardening furnace in Critical Points for last November and the remarks in June about "How to Avoid Distorted and Cracked Dies" are really two chapters of a single more important story which started a dozen years ago, namely, the development of a moderate cost, air hardening toolsteel for general purpose use. Jim Gill thinks the beginning probably was the low carbon 5% chromium

steels originated for still tubes for petroleum refining. Shortly thereafter 1% tungsten was added for a nitriding steel, and then a 1% molybdenum steel appeared in competition. The latter steel with carbon increased to 0.30% has, since 1932, been widely used for die casting dies, and is an air hardening steel with some secondary hardening on tempering. 4% chromium air hardening steels with 1% carbon and 0.5 to 1.0% molybdenum have been on the market even longer. . . . . So, when HOWARD SCOTT approached the problem of hardening intricate dies at the Westinghouse laboratory, a considerable background of experience with inexpensive steels existed. Obviously, two problems were interlocking, one the steel and the other the hardening furnace and method. Which had priority is probably as curious a question as the one about the hen and the egg. At any rate, the story goes that SCOTT and NORMAN STOTZ (of Universal-Cyclops Steel Corp.) got their heads together, concocted some new analyses, and tested them. Finally selected as best was one containing, roughly, 1% carbon, 5% chromium, 1% molybdenum. This steel is now offered by most American toolsteel makers and has been widely used because its several advantages usually outweigh its disadvantages. (Like everything in this world, it's a compromise!)

inexpensive air hardening, non-deforming toolsteels

It appears that it has greater toughness than the oil hardening toolsteels; due to the fact that it hardens in still air, the size changes are small and relatively predictable. Wear resistance is excellent, since the structure is well supplied with carbide particles. In ordinary sections the hardness after air cooling is Rockwell C-65; tempering a fully hardened piece at 950° F. reveals a moderate secondary hardening, Rockwell then being C-58 to 59. Although the steel is definitely not a "hot die" material, it nevertheless has some application for moderately hot work, helped by this secondary hardness.

GORDON WILLIAMS writes that its advantages are great and its disadvantages are not severe. Quenching temperature is high (1800° F.) and may tax some equipment. Differential hardening is not feasible. Unless one has a suitable furnace, scaling will accompany air cooling — although certainly most users harden the general run of work from the customary tool room furnaces. Protective paints help. Tendency to decarburization, particularly at the high hardening temperature, makes packing or use of an atmosphere-controlled furnace almost obligatory for work of high accuracy. Machinability is none too easy, even if carefully and appropriately annealed, although it is still much better than the older and twice as costly 12% chromium air hardening toolsteels.

By substituting manganese for some of the chromium, the quenching temperature is lowered 200° or so, and at least two toolsteel makers prefer this variation. Secondary hardening does not show up on tempering these steels, but they do harden deeply. The manufacturers point out that the lower quenching temperature reduces danger of decarburization and adapts these steels for use in tool rooms having difficulties at the higher temperature required for the 5% chromium type. This class of steels is of the same general nature as the older 4% chromium steels mentioned at the outset, widely used for hot dies. Certain it is, however, that a new family of toolsteels is available today having great value for many applications, which may largely supplant the good old "non-deforming" oil hardening steel, selling at the same price.

COMES NOW a protest from ROSS PURDY, general secretary of the American Ceramic Society, about using the term "metal ceramics" to denote the mixing of metal powders and the molding and firing of articles made therefrom. SAM HOYT (whose articles in METAL PROGRESS on powder metallurgy are the offending ones) writes that the term was used around the research laboratories in Schenectady 13 or 14 years ago during the development of Carboloy, and later appeared as the title of SKAUPY's German text on powder metallurgy. PURDY says that ceramic operations require clays and other oxide minerals, whereas powder metallurgy (even though the *operations* have a similarity) utilizes entirely different materials such as carbides, graphite and metals — metal even for binders. . . . . The EDITOR here forswears "metal ceramics", sympathizing heartily with PURDY's desire to reserve ceramics for the ceramic engineers. This is to be consistent, for he snorts at the chemist, who boldly, unblushingly and universally appropriates to "chemistry" the achievements of metallurgical engineers.

ceramics for the ceramist

NOTES ON THE CONDITIONING OF SEMI-FINISHED STEEL

This article on conditioning of semi-finished steel (that is, the chipping or scarfing of blooms to remove surface defects) was prepared by a special committee for the Metals Handbook, but was completed too late for inclusion in the 1939 edition. The personnel of the committee was as follows:

H. J. WEIGEL, Metallurgist, Youngstown District, Republic Steel Corp.;
A. BADGER, Metallurgical Engineer, Youngstown Sheet & Tube Co.;
L. FOGG, Inspecting Engineer, Youngstown Sheet & Tube Co.;
J. R. ANDERSON, Metallurgical Engineer, Carnegie-Illinois Steel Corp.;
A. P. SPOONER, Metallurgical Engineer, Bethlehem Steel Co.; and
J. H. FLAHERTY, (Chairman) Metallurgist, Aliquippa Works, Jones & Laughlin Steel Corp.

SEMI-FINISHED STEEL is defined by the American Iron and Steel Institute as the class that includes cast ingots and rolled blooms, billets, slabs and sheet bars. Of these several products, this discussion will refer chiefly to blooms, billets and slabs, and to a related product, seamless tube piercing rounds, which for convenience may be added to the definition.

Conditioning Standards: Conditioning of semi-finished steel, that is, the removal of surface defects, is frequently necessary to insure satisfactory surface in the finished product. The amount of conditioning required will depend upon the relative quality of the semi-finished steel and the type of product into which it will be rolled. For example, a bloom that would be entirely satisfactory for re-rolling into a structural beam might require considerable conditioning if it were to be rolled into a round intended for the production of pierced seamless tubing. Thus, all conditioning of steel is performed to meet specific standards of quality.

Special Operations Related to Conditioning: Rolling to semi-finished steel sometimes includes such special operations as double heating and double conversion. All of these special operations increase the cost of production due to extra equipment, slowing the operation, extra handling, and additional heating. In the case of double heating and double conversions, the ingots are reduced to a large bloom size, the bloom is partially or wholly cooled, then reheated for rolling to the desired bloom size. In the case of reheating, the additional heating removes some of the surface defects by the second scaling; in the case of double conversion, in addition to the extra scaling, the surface is conditioned by scarfing or chipping before reheating.

Cleaning for Conditioning: While no special preparation is needed for most steel prior to conditioning, it is necessary for a number of applications to clean the surface free from scale so that the defects may be more easily detected. Some of the more common cleaning methods are the use of high pressure water, flame de-scaling, pickling, sand and shot blasting.

(a) High pressure water is often applied to the hot surface of the steel during and just after rolling. The low temperature of the water chills and loosens the scale and the high pressure washes it away from the steel surface, leaving only a light layer of tight surface scale which permits a fair degree of inspection for surface defects.

(b) Flame de-scaling is performed on cold steel, by using a gas-burning torch to heat and expand the scale and loosen it from the cold steel underneath. This method, as a general rule, is not effective on steel finished at temperatures lower than 1700° F.

(c) Pickling, which is the oldest and most common method of scale removal, is accomplished by placing the steel in a 5 to 10% solution of sulphuric acid at a temperature of 150 to 200° for a period of from 15 to 60 min.

(d) Sand or shot blasting is the application of fine sand or shot to the surface of the steel either by air pressure or by centrifugal force against the object to be cleaned.

Conditioning Methods: The various methods of steel conditioning were developed to remove surface defects which would otherwise reduce the yield and quality of the finished product. Regardless of the method used, it involves the removal of surface metal and is carried out in a number of ways.

Hammer Chipping: Since the days of the first blooming mill and finishing mill, there has been some chipping-off of slivers and scabs from billet surfaces by hand tools so that the steel could be re-rolled without damaging roll guides or going into scrap. In some branches — especially in the rail mills, even in the early days — blooms were chipped to improve the yield and to prevent flaws in the finished product. In the late 1890's the invention of the pneumatic chipping hammer was an important development, and for years this continued to be the main tool for conditioning steel.

The metallurgy and design of the chipping chisel have received considerable attention during this time. In general there are two types of chisels, one rather narrow in width with a fairly small radius, adaptable for gouging out fairly deep seams; the other is relatively wide with a larger radius at the cutting point which covers a greater area to a lesser depth in the bloom. One of the main requirements is that the cut be well flared out so that a fold or lap does not develop along the chipping cut in subsequent working of the steel. The requirement for flaring usually needs a minimum width at least four times the depth of cut. Maximum depth of cut is $\frac{1}{16}$ in. per in. of section to a maximum depth of $\frac{3}{4}$ in.

Mechanical Chipping: There are, today, two distinct types of mechanical chippers. One is known as the Putnam Gouger and operates like a planer. The other is known as the Bonnot Machine and operates like a milling machine with a number of cutting tools fixed to the circumference of a revolving head. Both methods are effective and economical in conditioning steel which requires the removal of considerable metal from its surface. However, mechanical chipping can also be used very effectively on spot chipping.

Grinding: While only a relatively small amount of semi-finished steel is conditioned by grinding, this method is sometimes necessary due to the hardness of the steel or where the service intended for the finished product is such that only a complete removal of the billet or bloom surface offers sufficient insurance before proceeding with finishing operations. There has been considerable investigation of the abrasives, binders and the peripheral speeds of grinding wheels to speed up grinding action, but grinding is (and probably will continue to be) a very slow, costly method of conditioning, applicable for these reasons only to special cases where the grade of steel or its hardness make other conditioning methods impracticable.

Scarfing: In scarfing of cold steel a gas-burning torch is used as a tool for removing surface defects. There has been an extensive development of torches, gas generator plants, and incidental equipment for steel mills as a

Swing Grinders Clean the Entire Surface of Toolsteel Billets. Photo by Harbaugh for Jessop Steel Co.

result of the increasing use of scarfing, and to a major degree the torch has supplanted the pneumatic chipping hammer, especially on large sizes of blooms and billets. There is some possibility that the surface may check due to temperature effects and cooling stresses which become pronounced on some of the harder carbon and alloy grades. Precautions are necessary to prevent this.

Preheat Scarfing: Preheat scarfing, an intermediate modification of the plan of scarfing during rolling and scarfing of cold steel, is employed where steel chemistry, size, or atmospheric temperature, or a combination of any of these factors, militate against satisfactory scarfing of cold steel. The following procedures are those commonly followed.

(a) Scarfing is completed while the steel is cooling down from the finishing temperature, but before it has dropped below a safe minimum. Cooling after scarfing should be retarded.

(b) Steel which has become cold is reheated sufficiently to permit the completion of scarfing before steel has cooled below a safe minimum temperature. Cooling after scarfing to be retarded.

Mechanical Scarfing: Mechanical scarfing is used on material which requires a large amount of surface removal or where the material may be advantageously conditioned hot. Machines employing gas-burning torches in multiple are in use for partially or wholly removing the surface. One type is installed in the rolling train and the surface is removed at rolling temperature. The other type is employed in a manner similar to mechanical chipping, except that the material may be conditioned hot as well as cold.

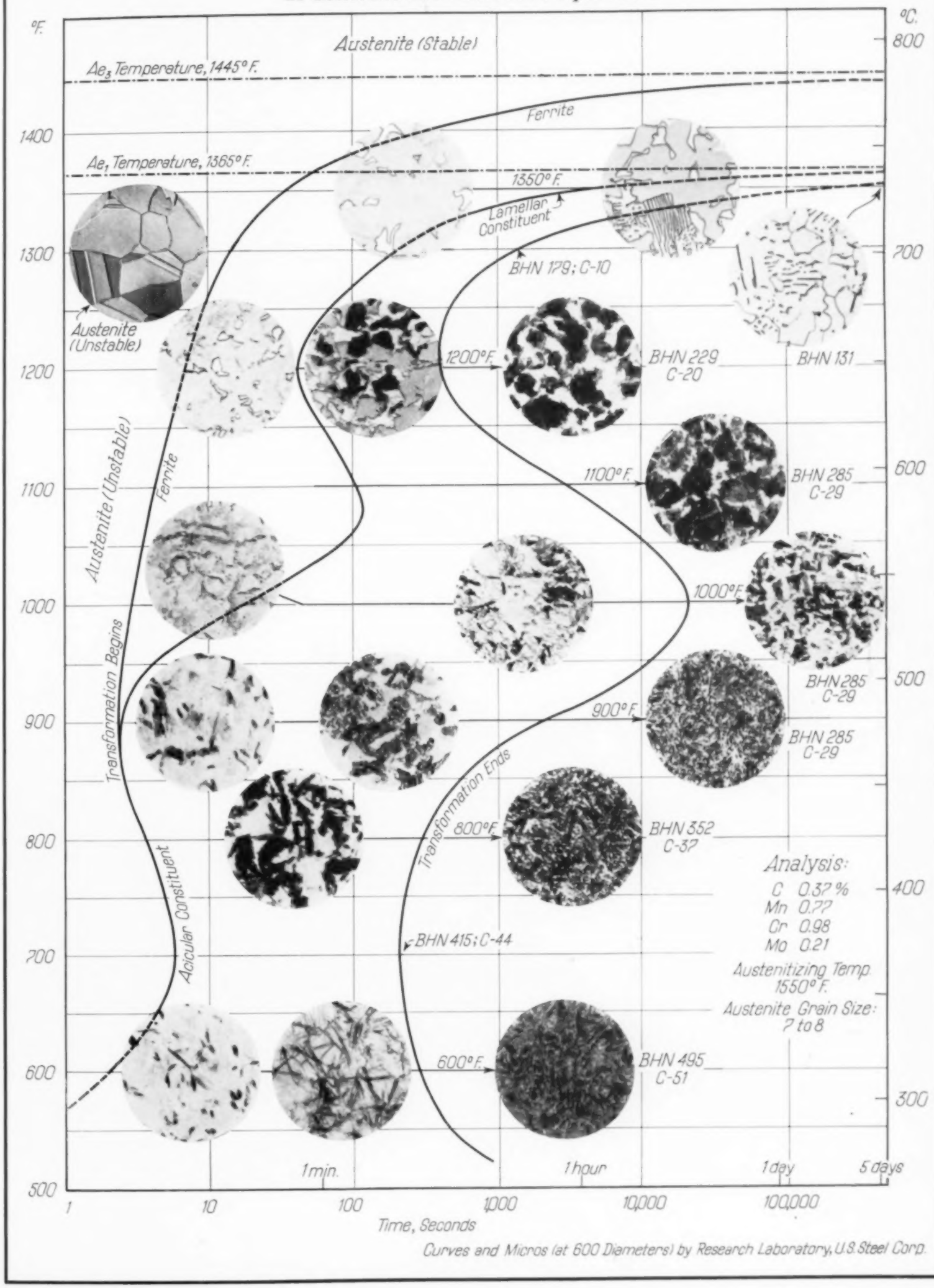
Peeling of Round Billets: Peeling a $\frac{1}{8}$ to $\frac{1}{4}$-in. layer off the surface of seamless tube round billets in large, rugged lathes was developed for the purpose not only of removing obvious surface imperfections but also exposing hidden defects which lie just under the surface of the steel. This form of conditioning possesses the advantage that no cleaning is necessary before peeling and, being a purely mechanical operation, the amount of labor necessary is exceptionally small. Peeling is more economical for the larger sizes of rounds, due to the lower percentage of waste material. This method requires additional scarfing or chipping labor to remove any deeper defects which may be revealed.

General: This description is limited to methods of conditioning in current use. However, the subject contains implications of broad metallurgical and commercial significance, including (as it might) considerations of the nature and causes of defects, mill costs, yields, alternative metallurgical measures that may be used to avoid or minimize conditioning, chemical and interior inspections exercised coincidentally with conditioning, relationship with trade requirements — all of which matters are involved in a broad view of the problem of conditioning.

Flame Descaling 31-In. Ingot of Alloy Steel With Flat Multi-Flamed Oxy-Acetylene Tips Mounted on Wheeled Carriage. Courtesy Air Reduction Sales Co.

Transformation of Austenite in 4140 Alloy Steel

at Constant Sub-Critical Temperature

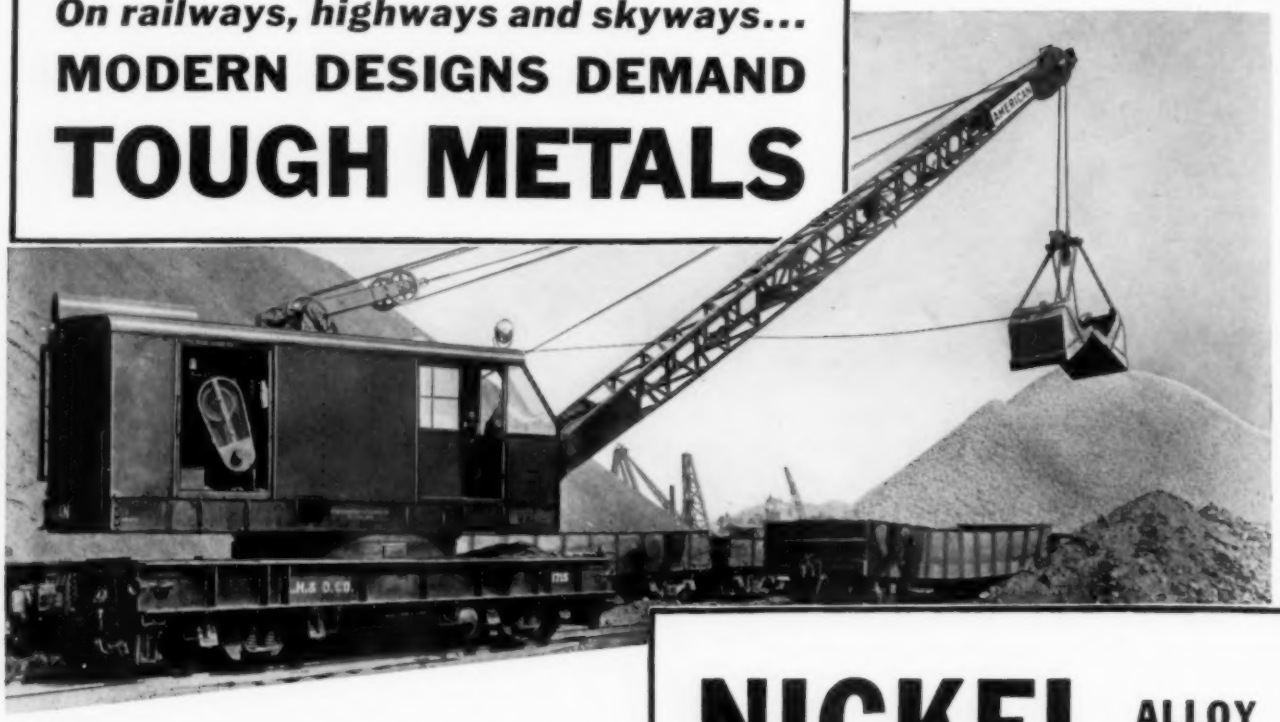


Curves and Micros (at 600 Diameters) by Research Laboratory, U.S. Steel Corp.

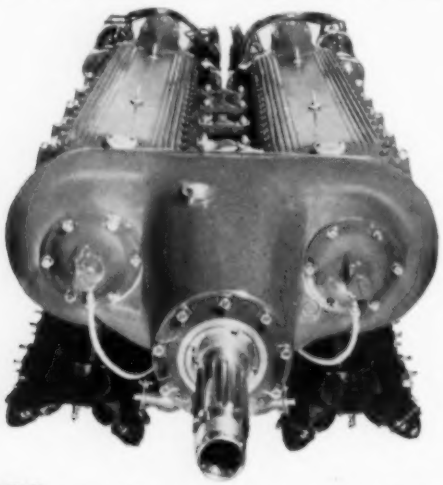
On railways, highways and skyways...

MODERN DESIGNS DEMAND

TOUGH METALS

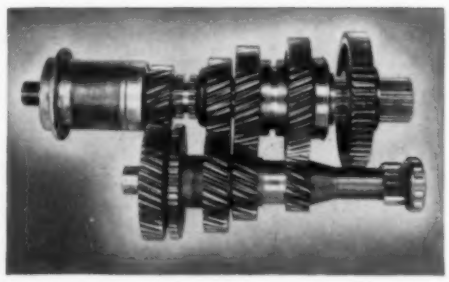


CRANES—Whether you build cranes, planes or truck transmissions, 1940 competition demands efficient, compact designs. Such designs are economically practical when you specify tough, long wearing Nickel alloy steels for stressed units. This modern locomotive crane manufactured by the American Hoist & Derrick Co., St. Paul, Minn., utilizes Nickel steels with tensile strengths up to 115,000 lbs. per square inch for stressed shafting, gears and pinions.



MOTORS—Airplane motors must not fail, so the Menasco Manufacturing Co., Los Angeles, Calif., assure dependability in their "Unitwin" motor by using tough, strong, long-serving Nickel alloy steels for all important parts. The new "Unitwin" consists of two separate in-line engines, generating 325 h.p. apiece, geared to drive a single propeller. The "Unitwin" is used in Vega six place "Starliner" planes.

NICKEL ALLOY STEELS



TRUCK TRANSMISSION PARTS

must withstand rough usage and abuse in service. Therefore, the manufacturers of the heavy duty transmission illustrated here, The Four Wheel Drive Auto Co., Clintonville, Wisconsin, specify Nickel alloy steels to assure safe extra strength and toughness in light weight stressed parts. This transmission is especially designed for heavy duty four-wheel drive service, having a torque capacity in excess of the largest engines available.

➡ Heat treatable, readily machinable steels containing Nickel may enable you to simplify design and speed up production. Our suggestions are based upon the practical experience of many plants. For information, without obligation, please address:

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK, N. Y.

POWDERED METAL COMPACT BONDS BABBITT TO STEEL BACK

By Roland P. Koehring
Research Engineer
Moraine Products Division
General Motors Corp., Dayton, Ohio

IT IS common knowledge that shaft bearings, once comparatively husky blocks of bronze, or cast iron boxes lined with babbitt, persist now mainly in massive stationary machinery—although even in such service many ball and roller bearings are being installed. In high speed mobile equipment, and all places where weight or volume is at a premium, the bearings have been highly refined in design. Going on the assumption that only the *surfaces* of the bearing and its adjacent shaft and the intervening oil film are involved in any anti-friction device, the trend has been to make both surfaces highly accurate and of proper structural characteristics, and to align the parts correctly. As far as the bearing itself is concerned, only the merest film of special alloy should theoretically be necessary; it must be supported by a backing stiff enough to avoid change of shape during handling and installation, and then mounted in a closely fitting cavity in the frame or supporting structure. This frame really carries the loads. [A pictorial story showing how such modern babbitt bearings are made appeared in METAL PROGRESS in June 1938.]

It is also common knowledge that bearing trouble, in an automobile for instance, is now almost non-existent unless the machine is grossly overloaded or lubrication neglected. However *that* is no reason why automotive engineers should be satisfied with what they have got. A better bearing would enable higher loads to be carried at higher speed, and thus either increase the safe power from a given engine size, or decrease the size for a given rating. Such a bearing has actually been achieved as a result of a long development by engineers on Buick Motor Division's staff, working in cooperation with those of Moraine Products Division of General Motors Corp. Laboratory and road tests show that the new bearing, known as "Durex No. 100", has a minimum life expectancy at least 200% over the ones formerly used as main bearings in Buick automobile engines.

Requirements for an ideal bearing were outlined over five years ago, at the outset of the research, by A. F. UNDERWOOD, head of the mechanical engineering department of General Motors Research Laboratories:

1. Fatigue resistance should be high, to satisfactorily withstand the imposed load at the operating temperature.
2. Mechanical strength: the ability of the bearing to resist extrusion and pounding.
3. Good bonding characteristics.
4. High melting point. The bearing material

must have a high melting point so as to retain its mechanical strength under operating conditions.

5. Low friction and non-scoring characteristics to prevent galling or over-heating.

6. Conformability; ability of a bearing to adjust itself to shaft deflections and deformation under maximum loads.

7. Embedability; ability of the bearing material to absorb dirt and worn off metallic particles, thus preventing such foreign materials from contaminating the pressure lubricating system.

8. High corrosion resistance.

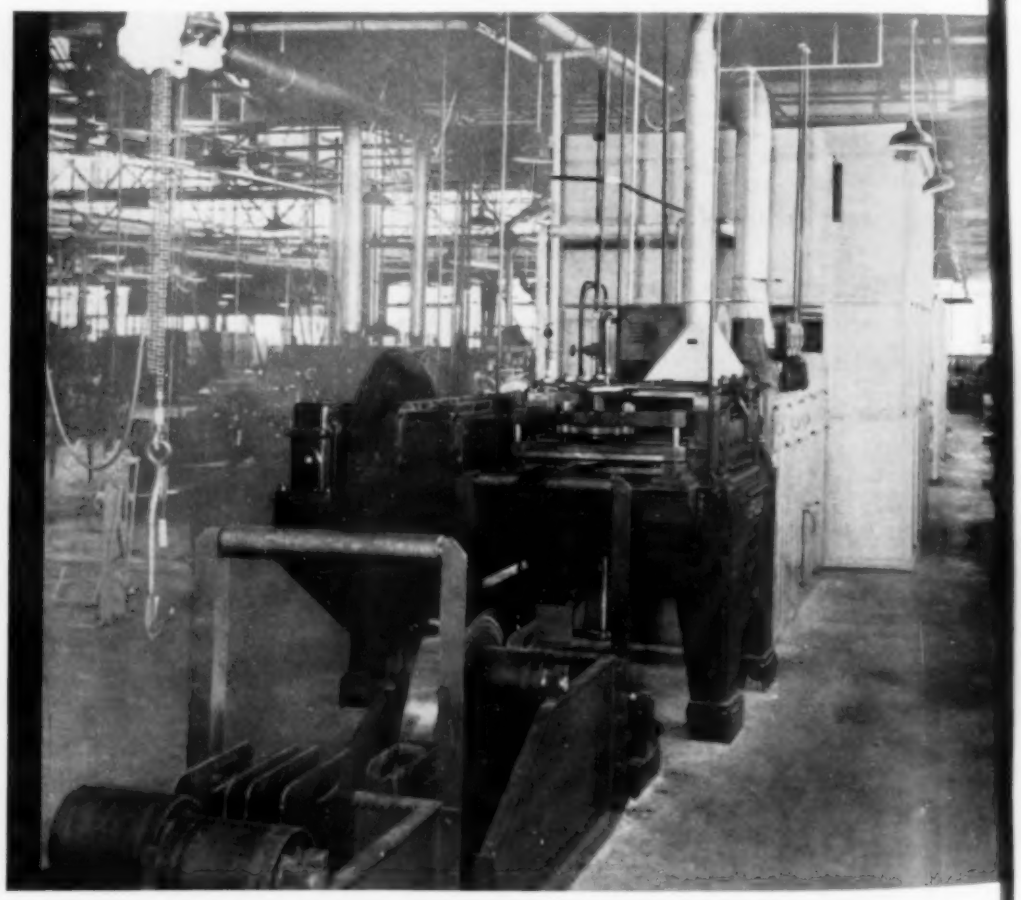
Turning to the bearing material, the mass of experimental evidence and service history indicated that the most suitable alloy is the one generally known as the high-lead babbitt type, which possesses unique properties of resistance to wear, scoring and corrosion from organic acidity of the type normal to lubricating oil. In addition, it was agreed that the alloy should be relatively soft so as to prevent wearing on crankshaft journals and pins, thus retaining the original bearing fits and consequently maintaining fine balance and smooth running.

"High-lead babbitt" has been known and used for many years. In fact, two Society of Automotive Engineers' standards (No. 13 and No. 14) cover materials with 86 and 76% lead, respectively, balance antimony and tin. Custom calls these alloys "babbitt" although the original bearing material of this name was largely tin. Both tin-base and lead-base babbitt have low resistance to fatigue. Fortunately, the accumulated service history showed unmistakably that fatigue failure, as evidenced by cracking and actual breaking out of portions of the bearing surface, was related to the use of a relatively thick layer of babbitt.

Studies also revealed that practically all fatigue cracks were typically of about the same depth. Incipient fatigue failure begins in the form of fine radial cracks or fissures in the surface, growing in depth with time. Eventually, at a certain depth these radial cracks are joined by short circumferential cracks deep in the structure of the metal. When this network of cracks is completed it results in the loosening of fairly large areas of metal which tear or melt out of the bearing with damaging results.

Further work along this line proved conclusively that if an extremely thin layer of bearing material were employed, incipient fatigue cracks postponed their appearance or required higher stresses. Moreover, if radial cracks did develop there was little or no opportunity for the development of connecting circumferential cracks which are responsible for the tearing out of chunks of the bearing material.

It was obvious, however, that an extremely thin layer of babbitt would be difficult to use unless means were found for bonding it securely and permanently. Unique feature of the new bearing is the introduction of an extremely strong but porous "matrix" bonded directly to the steel back. By virtue of the technique of powder metallurgy, this matrix, composed of a mixture of 60% copper powder and 40% nickel powder, is sintered and brazed to the steel back under controlled conditions which produce a porous structure into which



Entrance End of Production Line. Strip, in rolls, goes through roller leveller and washing machine before entering powder metal room in background

the babbitt interlocks both chemically and by mechanical interlocking.

The bearing surface itself is a special high-lead composition containing 92% lead. By the use of the special matrix, it is possible to produce a layer of babbitt only 0.002 in. in thickness over the matrix, assuring permanency of the bond as well as freedom from fatigue failure encountered with thick babbitt coatings.

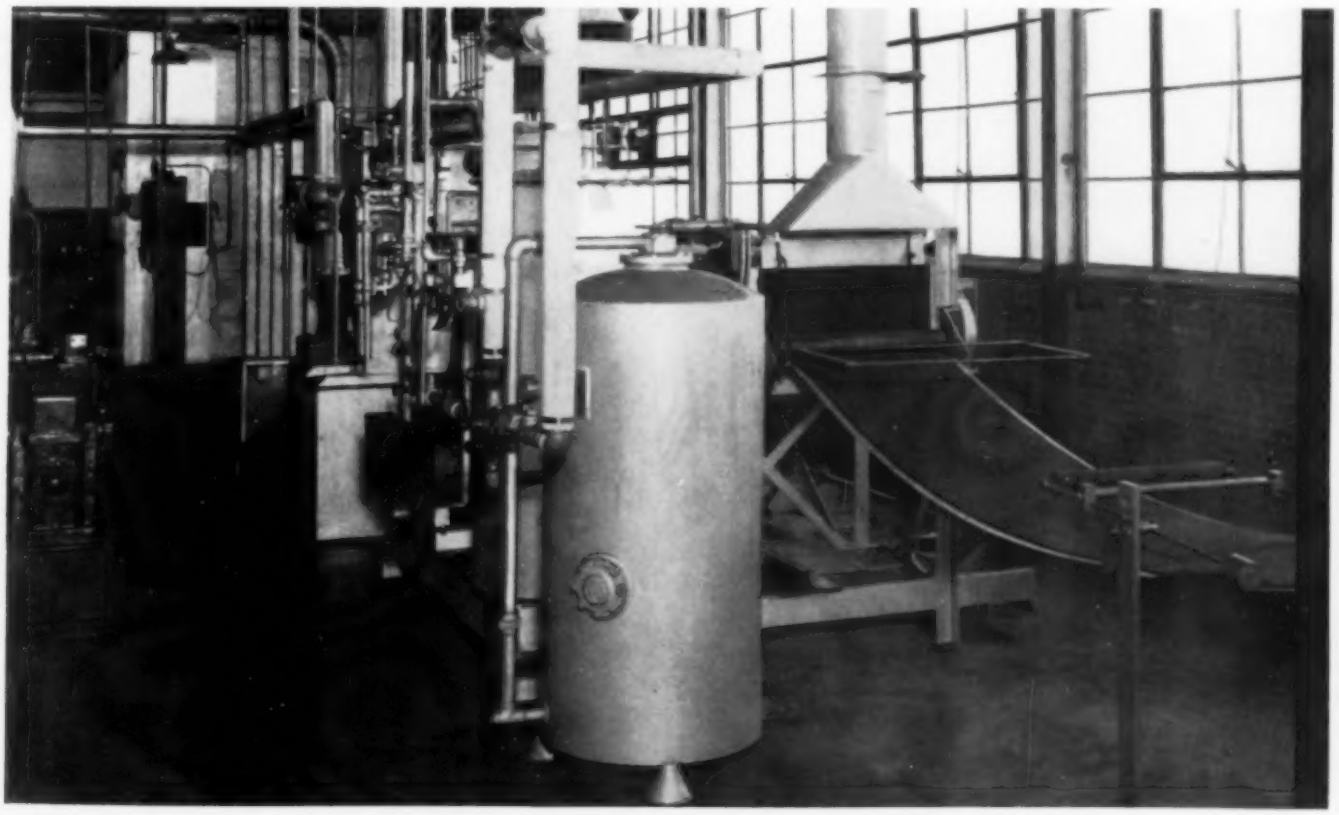
The matrix is really the heart of this particular bearing, providing not only a positive means of locking the babbitt but also improving the heat conductivity. Since the matrix must be capable of carrying the high unit loading characteristic of modern high performance engines, means have been taken to give it the ability to support loads far in excess of present practice. To this end, at one stage of the manufacturing process, the steel strip coated with the matrix is passed through a series of chromium-plated embossing rollers which squeeze the matrix with a pressure up to 10,000 psi. Considering that the most severe service imposes a loading of only about 2,000 psi., it is evident that the new Buick bearing has a large reserve of load carrying capacity.

In addition to this necessarily brief discussion of the metallurgical development of the Durex No. 100 bearing, it will be possible to describe the details of the manufacturing methods whose development has paralleled metallurgical research and complemented it.

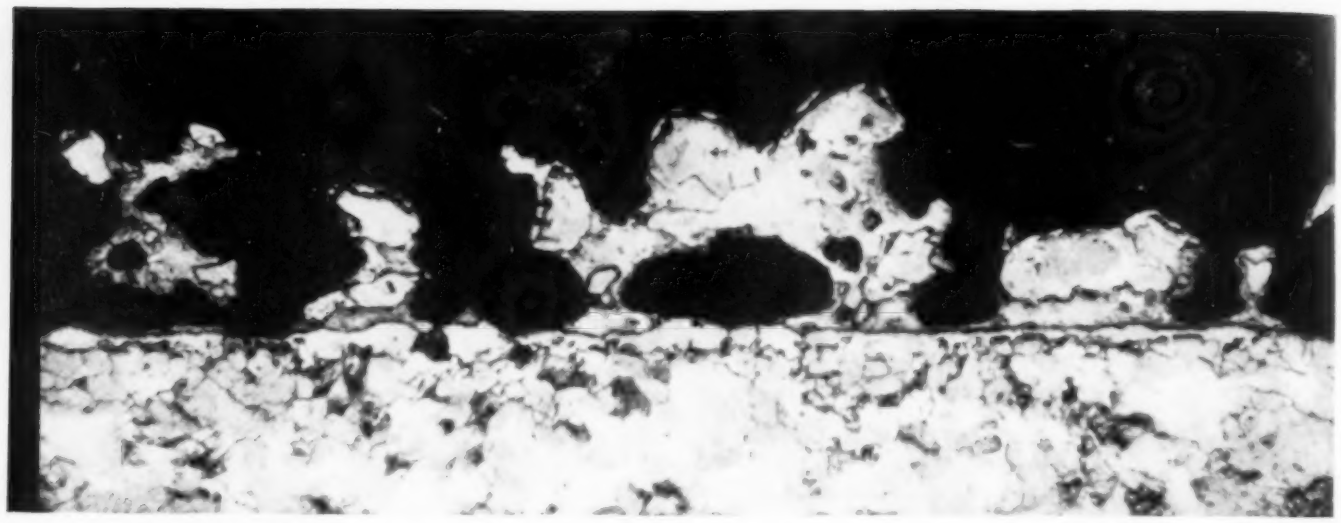
As will be noted from the illustrations, there are three separate stages or lines in the production set-up. Two of these utilize new equipment designed specifically for the purpose.

The first line is concerned entirely with the application and sintering of the matrix. The second line is devoted to the formation of the babbitt coating and the preparation of blanks ready for the final forming and machining operations. The third is a conventional set-up required for finishing formed half-shells. All are synchronized as to speed, creating a continuous and connected family of operations.

In the first line, shown on these two pages, steel strip is fed from coils. The strip is of S.A.E. 1010, cold rolled, with thickness held to close tolerances. It is fed through a roller leveller to flatten it free of crown and lengthwise distortion. Then it goes through an alkaline wash and drying machine to clean the surface of dirt and oil. From the washer, the strip is carried into the powder room through



Strip Leaves Powder Room (Extreme Background) Carrying Thin Layer of Copper-Nickel Powder and Enters Long Furnace Where Powder Is Sintered and Bonded to Steel Strip. Wide strip is cooled and emerges, ready for compacting and babbitting



Cross-Section (at 60 Diameters) of Durex Bearing. Steel base below, to which a 60-40 copper-nickel powder is sintered. High-lead bearing material (the dark upper portion) then fully impregnates the pores of this matrix

6-in. pull rolls which provide the desired tensioning in the feed.

In the powder room the matrix powders — copper and nickel — are mixed intimately in their proper proportions. This mixture is fed onto the continuously moving strip so as to provide a uniform layer of the powder. The feeding equipment can accommodate from one to five strips at a time, depending upon their width, taking strips from 1 in. to 20 in. wide, 0.020 to 0.150 in. thick, at rate variable from 6 to 36 in. per min.

As the strip leaves the booth, the steel back passes over a brush which removes traces of powder and dirt from the underside. The strip now continues through an Electric Furnace Co. furnace containing four precisely controlled heating zones. Here the powder is sintered in a prepared atmosphere into a porous matrix, of controlled metallurgical character, bonded securely to the steel back.

The heat zone of the furnace features a roller hearth 18 ft. in length; the cooling zone is 21 ft. long. At its exit there is a set of pinch rolls with tension control to take up the slack in the stock. Adjacent to the pinch rolls is a pair of chromium-plated sizing rolls. From this stage, the strip is led over rubber idler rolls to the battery of five recoilers which store the coated strip on individual reels.

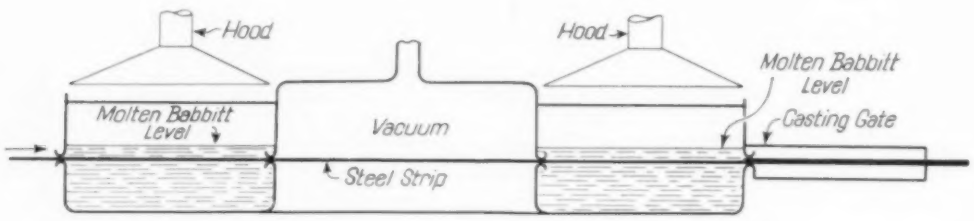
The reels now are transferred to the second line. Succeeding reels are joined, end to end, by automatic Federal electric resistance welder. As the strip leaves the welding stage, the flash is removed in an attachment supplied by the Morton Mfg. Co.

To provide the time for joining operations without slowing down or stopping the line, the strip passes through an ingenious slack adjustment mechanism consisting of four large pulleys with balanced tension, over and under which the strip weaves.

Next the strip passes through a set of chromium-plated embossing rolls which compress the matrix under high pressure, consolidating the powder-metal sinter and giving it uniform thickness. The next stage is the slitter which trims the bare sides to the proper width. Final step before entering the babbitting machine is another pass through a roller leveler.

The next stage is easily the most impressive and withal the most important: The babbitting operation is performed in a remarkable piece of equipment which may be described as a vacuum tunnel machine. Its principal features may be gathered from the diagrammatic sketch. The machine has three principal zones, the first, in which the strip is com-

(Continued on page 196)



Sketch Showing the Three Stages of the Vacuum Tunnel Babbitting Machine

CORRESPONDENCE & FOREIGN LETTERS

Transformations in S.A.E. 4140

Special letter to METAL PROGRESS
by E. S. DAVENPORT
Metallurgist
U. S. Steel Corp. Research Laboratory

KEARNY, *N. J.*—The isothermal transformation diagram for S.A.E. 4140 steel (reproduced in the data sheet, page 171) is substantially the same as that which appeared as Fig. 24 in the 1939 Campbell Memorial Lecture (*Transactions* ASM, Vol. 27, p. 837; METAL PROGRESS, November 1939, p. 628). There is, however, the additional feature of the photomicrographs showing the progress of transformation and the nature of the transformation product at a number of different temperature levels; in this respect the present chart parallels the large one for eutectoid carbon steel issued some years ago and reproduced as a data sheet on page 374 of the 1939 October Reference Issue of METAL PROGRESS. Note, however, that the S.A.E. 4140 diagram is carried down only to about 500° F.; for the lower portion of this diagram reference should be made to the 1939 Campbell lecture.

At each temperature level, the left-hand micrograph represents an early stage in the transformation (not more than 5 to 10% transformed), the middle micrograph represents about 50% transformation, while the right-hand micrograph shows the structure upon completion of isothermal transformation. Note that the first stage of transformation at the higher temperature levels (1000° F. and above) consists of the rejection of pro-eutectoid ferrite; this first stage of the reaction is clearly distinguishable from the subsequent transformation to the "ferrite plus carbide" aggregate product (the lamellar constituent, clearly resolved when transformed at temperatures above 1200° F.).

Brinell and Rockwell hardness of the product of complete transformation at each temperature level is indicated on the chart, together with pertinent data. All photomicrographs were taken at an original magnification of 1000 diameters and reproduced in the data sheet at 600.

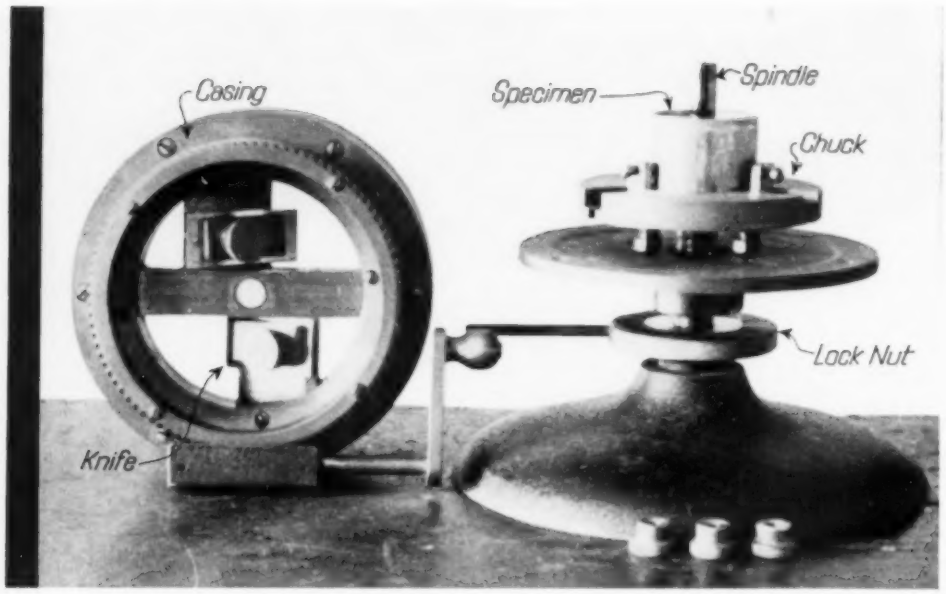
E. S. DAVENPORT

Sigma Phase

(Temporarily Resurrected)

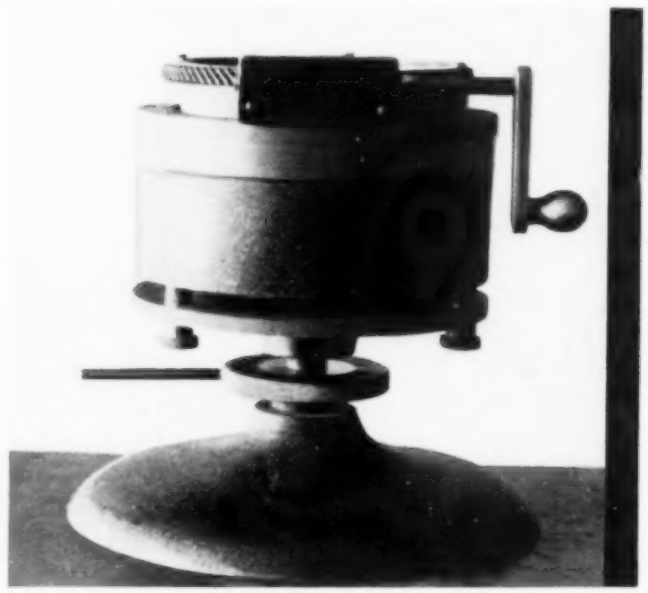
Special letter to METAL PROGRESS
by J. H. G. MONYPENNY
Metallurgist
Brown, Bayley's Steel Works, Ltd.

SHEFFIELD, *England*—In METAL PROGRESS for May, your genial correspondent MARTIN SEYT, writing under the title "Sigma Phase (Finis)" talks of tents and tunnels, holidays and fortifications, blockades and control, and the significance of Greek letters in a delightfully inconsequential manner which is refreshing in these days of stress and trouble. His idea of a blockade control, which seemingly not only removes the machinations of spies but, like the genie of a fairy tale, can put the clock back and exercise its powers, whether beneficent or sinis-



(At Left) Microtome Opened for Insertion of Specimen of Cable Sheath Into Chuck. Knife is rotated around spindle by worm drive; frame carrying it moves in accurate slide inside the casing

(Below) Microtome Assembled for Cutting



ter, on events which occurred six months before, is particularly interesting. It might well form the basis of a new "thriller" on modern war!

Possibly, however, the high spot of Mr. SEYT's airy dissertation concerns the relationship of "tent" and "tunnel" and, as this seems still a little confused, the present writer may perhaps be forgiven for suggesting that the difference between the two is something more concrete than mere ideology.

Tents, as Mr. SEYT suggests, conjure up visions of camping holidays, of a carefree life with the more solid paraphernalia with which most of us, following the dictates of fashion, surround our ordinary life, left behind at home. One travels light on such holidays and a tent may therefore suggest a slender construction with weight cut down to a minimum, needing no special foundations of its own, not pegged down to some particular spot but erected where fancy dictates and serving with a greater or less measure of success (depending, at least in this country, on whether Jupiter Pluvius is smiling or tearful!) a temporary and frequently short period of usefulness after which it is discarded in favour of a more substantial habitation.

A tunnel, on the other hand, conveys the idea of a massive construction, needing the digging of foundations, the clearing away of earth and rubbish in order to get down to bed rock, and the surmounting of one obstacle after another before it emerges into the daylight beyond. When finished, it has some considerable measure of permanence.

Which thing is perhaps an allegory!

J. H. G. MONYPENNY

A Microtome for Lead Cable Sheath

Special letter to METAL PROGRESS
by HERLUF P. NIELSEN
Associate Professor of Metallurgy
The State College of Washington

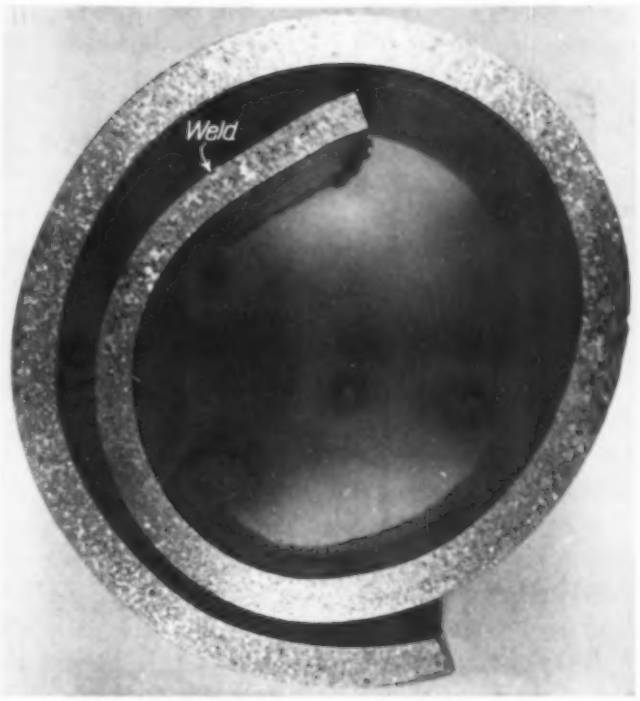
PULLMAN, *Wash.*—Some time ago the writer had occasion to examine a large number of sections of extruded lead cable sheath for grain size, inclusions and laminations. The cable was of a large size, 3 to 4 in. in diameter, and polishing of the complete section by hand rubbing on kerosene-covered emery paper proved to be a long and tedious operation. I have read that the Germans are trying to use aluminum for such sheathing; maybe they got tired of polishing lead! Since macro rather

than micro-inspection is generally sufficient for this type of work, it was thought that a simple type of microtome could be built which would completely eliminate the polishing operation. The machine shown in the illustrations was the result, and is the skilled handicraft of ANDREW MAITLAND.

The first view shows the microtome opened for fastening the cylindrical specimen in the chuck. Three screws are tightened on the specimen and it is then pulled tightly down on the chuck disk by springs. The three springs are tightened (or released) simultaneously by turning the large disk upon the vertical main spindle, upon which a fairly fine thread has been machined. The two microtome knives, shown at the left of the view, are driven by the worm drive and hand lever, and rotate between carefully spaced guides in the inside surface of the circular casing.

After securing the specimen in the chuck, this casing, with the knives, is placed over the specimen and fastened to the large disk, as shown in the assembly. The microtome is then ready for work. The knives are lowered the desired amount by turning the casing upon the threaded spindle, and the cut is taken all the way around by turning the crank which drives the worm gear.

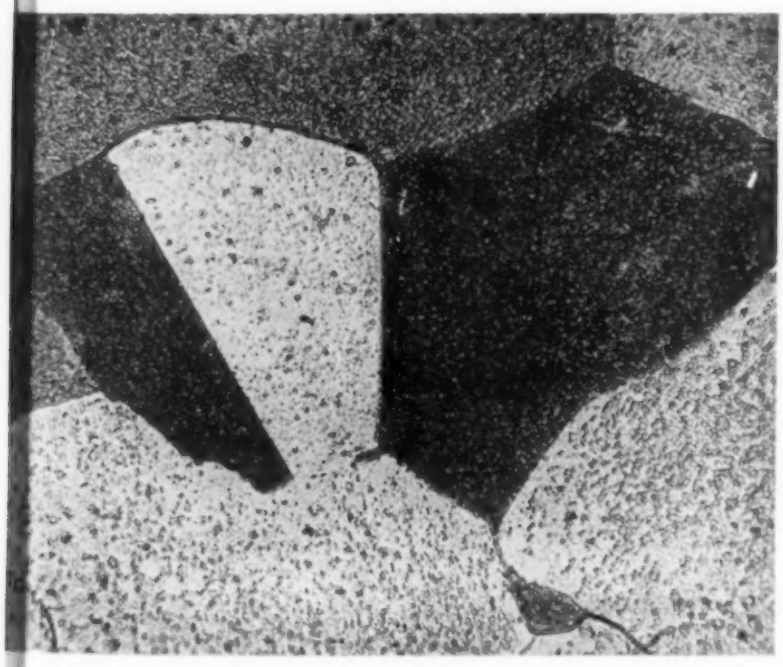
The knives must be carefully sharpened, using progressively finer grades of metallographic emery paper and finishing with rouge and kerosene on plain paper. One knife is used for roughing cuts and the other for finishing. Cuts thinner than half a thousandth of an inch are easily obtained, and a specimen can be prepared with the aid of this machine, ready for etching, in less than 5 min.



Typical Macrograph of Lead Cable Sheath (Actual Size) Split and Curled to Save Space in Photographing

For etching, the solution recommended by LUCAS has been found the most satisfactory. It consists of 3 parts glacial acetic acid, 1 part 30% hydrogen peroxide and is swabbed on the cut surface until the grains are clearly brought out. It may then be necessary to clean the etched surface by dipping into concentrated nitric acid. A typical macrosection is also shown of a cylindrical specimen, split and wound in a spiral to save space in photographing. A weld can be seen a short distance from the end on the inside. This appears to be a good quality sheath except for the fact that it varies considerably in thickness. The weld was examined under the microscope at 50 diameters and found to be delineated by a row of tiny crystals, possibly caused by a large number of very small inclusions.

We have frequently photographed, at quite high magnifications, the surfaces prepared with the microtome. A specimen magnified 500 diameters is shown. Such magnifications are of course more desirable where the grains are extremely small.



Micro at 500 X of Lead Microtome Cut, Etched With Lucas' Solution of Hydrogen Peroxide and Acetic Acid

HERLUF P. NIELSEN

Static Crack Strength of Metals

Special letter to METAL PROGRESS
by D. J. McADAM, JR.
Metallurgist, National Bureau of Standards

WASHINGTON, *D. C.*—I would like to comment on the paper of the above title by MAXWELL GENSAMER appearing in METAL PROGRESS last month. This discussion applies also to part of a paper by Mr. GENSAMER, E. B. PEARSALL, and G. V. SMITH on "The Mechanical Properties of the Isothermal Decomposition Products of Austenite" appearing in *Transactions* for June 1940.

In both these papers the authors investigate the technical cohesive strength of metals. Although the method used is said to be based on the fundamental investigations of W. KUNTZE, and to be a modification of his method, the authors evidently misunderstood the German work. This is illustrated by the following statement on page 388 of the paper in *Transactions:* "The cohesive strength . . . . was calculated by dividing the load at fracture by the area of the specimen remaining after the fatigue fracture had been produced", and by the following statement on page 59 of the paper in METAL PROGRESS (which is the chief subject of this discussion and to which attention will now be confined): "This value (the cohesive strength) should be of interest to engineers, for it is the nominal stress required to propagate a crack in the presence of a very sharp and deep notch." According to KUNTZE's views, however, the resistance to propagation of a crack is a function of the depth and of the indices of ductility, whereas the technical cohesion limit is a fundamental property of the metal.

On the same page Mr. GENSAMER ascribed to KUNTZE the view that "the nominal stress required to break a cylindrical bar in which a sharp 60° notch was machined to such a depth that the remaining area was 31% of the original was within 90% of the ultimate crack strength obtained by extrapolation." (I assume that by "within 90%" he means "more than 90%".) Although KUNTZE may possibly have expressed such an opinion in an earlier paper, it is very different from the views elaborated in his 1932 book "Kohäsionsfestigkeit". He there reports that the ratio between the radial stress S_3 and the longitudinal stress S_1, in a cylindrical specimen with a Vee notch, is linearly related to a function of the depth, as in the equation

$$S_3 \div S_1 = C(D^2 - d^2) \div D^2 \qquad \text{Equation I}$$

in which d and D represent the minimum and maximum diameters respectively of the cylindrical notched specimen, and C is a constant depending on the notch angle. If $d^2 \div D^2$ be designated by k, the equation becomes

$$S_3 \div S_1 = C(1-k) \qquad \text{Equation II}$$

The ratio $S_3 \div S_1$ was also found to be linearly related to the notch angle, according to the equation

$$C = (180-\omega) \div 180 \qquad \text{Equation III}$$

in which ω represents the notch angle in degrees. By combining Equations II and III we get

$$S_3 \div S_1 = (1-k)\ (180-\omega) \div 180 \qquad \text{Equation IV}$$

For zero notch angle, $S_3 \div S_1 = 1-k$. For a value approaching zero of both ω the angle of notch and k the proportionate area carrying the load, S_3 the radial stress becomes equal to S_1, the longitudinal stress. This condition represents pure three-dimensional tension. In this imaginary condition, there would be no shearing stress, and the longitudinal stress would represent the technical cohesion limit.

KUNTZE found a similar relationship between the maximum tensile stress of a notched specimen and the depth and angle of the notch. The maximum tensile stress (based on the minimum section) was found to be linearly related to $(1-k)\ (180-\omega) \div 180$. This is the expression given on the right hand side of Equation IV. These linear relationships of both $S_3 \div S_1$ and the maximum tensile stress to the same function of k and ω are the basis of KUNTZE's estimation of the *Trennfestigkeit*. By determining the tensile strength of an unnotched specimen and of specimens with various depths of notch, it is possible to extrapolate linearly to zero section, for a specimen with the given notch angle, and then to extrapolate to zero section for an imaginary specimen with zero notch angle. Even after testing an unnotched specimen and another specimen having a notch of sufficient depth, it is possible to obtain an extrapolated value of the technical cohesion limit.

KUNTZE's method of linear extrapolation cannot be applied when the tension test of a notched specimen gives a "premature" fracture. The value used in his extrapolation is not the breaking stress, but the maximum tensile stress when the conditions are such that the load rises to a maximum (as in a test of an unnotched specimen) and then descends. Stresses based

on "premature" breaks, with rising load, do not give a linear relationship with

$$(1-k)\ (180-\omega) \div 180,$$

and may give a decidedly curvilinear one.

It is noteworthy, however, that Dr. GENSAMER says on page 61, "Properly cracked specimens break as the load is increasing; that is, there is no evidence of any yielding until fracture occurs. If the load reaches a maximum and begins to diminish before fracture occurs, the test is discarded, for this indicates plastic deformation preceding fracture." The results rejected were the only ones that could be used according to KUNTZE's method, which actually involves the determination of a series of values representing gradually decreasing plastic deformation, and the use of these values in linear extrapolation to obtain a value representing *no* plastic deformation (pure three-dimensional tension). If the cracked specimens give "premature" fractures, there is no established basis for determining the technical cohesion limit by extrapolation. Linear extrapolation apparently is possible only when the plastic deformation at maximum load is enough to relieve much of the stress concentration at the root, so that the chief effect of the notch will be due to the three-dimensional stress.

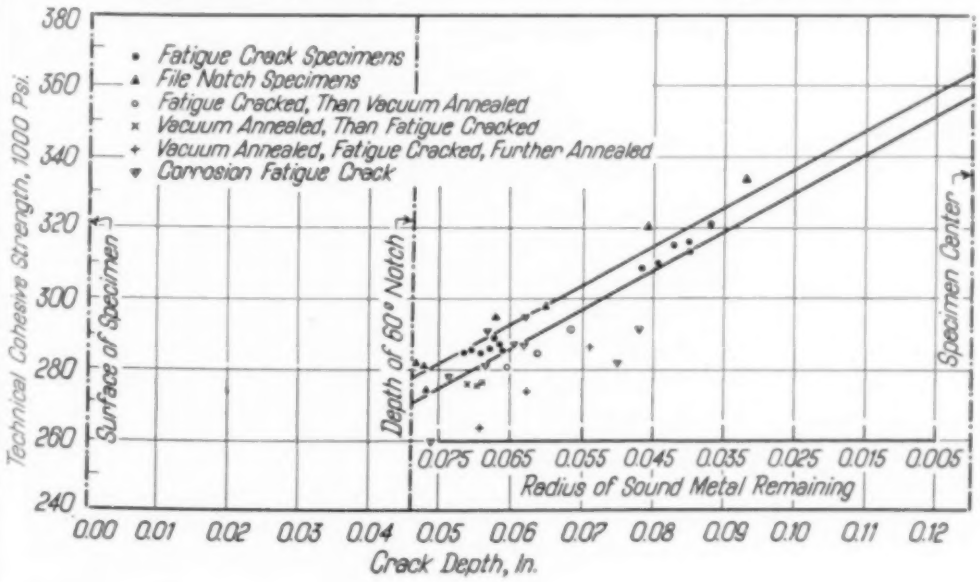
In the diagram reproduced below, linear extrapolation is used with abscissas representing radii of the specimen, whereas KUNTZE's method is based on linear extrapolation with abscissas representing sectional areas. As no value is given for the tensile strength of an unnotched specimen, it is not possible for the reader to estimate the *Trennfestigkeit* from any of the values given in this diagram. KUNTZE's method of extrapolation could be applied to a specimen with a machined 60° Vee notch, but would give no basis for extrapolation for a specimen having a 60° Vee notch with a sharp (0°) crack at the bottom. By machining the 60° notch away after starting the crack, KUNTZE's method could be applied if the crack were sufficiently uniform and if the tests did not give premature fractures. With a shallow crack, however, a large extrapolation would be necessary, according to Equation IV.

Non-uniformity of the circumferential crack used by Dr. GENSAMER would tend to cause eccentric loading in tension, and thus would tend to cause high bending stress. It is doubtful whether his "alignment sleeve" would fit closely enough to prevent some bending stresses, and consequent low values of the estimated breaking stresses.

Many of the values for the technical cohesive strength of quenched and tempered 0.80% carbon steel, given in the last diagram and discussed rather briefly in the last paragraph of the paper (p. 64) appear too low. The technical cohesive strength of a metal may be as high as twice the tensile strength as ordinarily determined from smooth specimens, but obviously can never be less than the yield strength so determined. When the ductility is small, cohesive strength could not be much less than the tensile strength, and the cohesive strength of a very brittle metal would coincide with the tensile strength as determined with an unnotched specimen. Many of the values given in the diagram appear too low to be in accordance with the probable values of yield point and tensile strength of such material. In discussing these values, the author apparently implies the possibility that heat treated bridge wire might sometimes have a cohesive strength of only 70,000 psi. Such defective material, however, would be revealed unmistakably by an ordinary tension test.

D. J. MCADAM, JR.

Correction: *This cut is from page 63 of Dr. Gensamer's article in the July issue, and has been corrected so the ordinates now read from 240 at the bottom to 380 at the top. Excuse our draftsman, please, for the Editor finds it difficult to do so!*



Dr. Gensamer's Comment

Dr. McAdam has incorrectly ascribed to me a claim to the measurement of the true cohesive strength. The fault is my own, for I have used the term "technical cohesive strength" to mean a different thing than he does. His statements are accurate insofar as they apply to the measurement of what Kuntze called the *Trennfestigkeit*, which I have translated as "cohesive strength" and distinguished from the "technical cohesive strength". The latter term I have applied, no doubt injudiciously, to what I should have and now prefer to call the "static crack strength". The misunderstanding this confusion of terms has caused is probably general, and therefore I am grateful to Dr. McAdam for calling it to my attention and for providing an opportunity to make myself clear.

I do not believe I am wrong in ascribing to Kuntze the statement that the technical cohesive strength (as defined in paragraph three of my paper but wrongly ascribed to Kuntze) should extrapolate to the static crack strength for a very deep notch (*Archiv f. d. Eisenhüttenwesen*, Aug. 1928, p. 109-117). For notch sensitive materials like steel Kuntze used a 60° notch with 31% remaining area, machined as sharp as possible (*Metallwirtschaft*, June 17, 1932, p. 343-347; also "*Kohäsionsfestigkeit*", Berlin, 1932). He stated (in 1928, but makes no reference to this in 1932) that the nominal breaking stress with this notch is at least 94% of the value to which the tensile strength extrapolates (not as a straight line) when plotted against angle and depth of notch. In the second paragraph of my paper I have incorrectly called this value the *Trennfestigkeit* according to the 1932 paper, but Kuntze also called it this in the 1928 paper, and determined its value from Ludwik and Scheu's data using sharp notches. I have called the breaking strength with the 60° notch the "technical cohesive strength"; Kuntze does not use this term in the papers referred to here. Perhaps carelessly, I have extended the use of this word to cover the breaking strength of a specimen with a sharp notch of any depth. This is the quantity in which I am interested and claim to measure with the fatigue crack or filed notch technique.

In developing his method for measuring true cohesive strength Kuntze showed that the tensile strength of notched specimens plots as a straight line against the angle of the machined notch when the notches are not really sharp, and for notch sensitive materials only for values of the notch angle lying between 180° (unnotched) and 120°. He takes the cohesive strength (not the technical cohesive strength as I defined it) as the value to which the tensile strength extrapolates for 0° notch angle and no remaining area. *(Cont. on p. 204)*

New Cutting Tools Will Speed Up Old Machines

Special letter to Metal Progress
by Donald G. Clark
Vice-President, Firth-Sterling Steel Co.

McKEESPORT, *Pa.* — Persistent assertions that machine tools and their operators constitute a serious national defense bottleneck are apt to be misleading, since they are based on an appraisal of peace-time production. Moreover, they do not take into consideration the full productivity of supplementary accessories developed during the past ten years.

While it is true that specially designed machine tools for every job would facilitate production of armament, a sufficient number of machines for this ideal setup may not be available for many months. Meanwhile we should press into service every piece of equipment now available, old or new, and use it to the limit of its capacity.

With respect to machine tool accessories, it is fortunate that cutting materials have been developed that are capable of such high production rates that they will compensate, to a considerable degree, for a possible shortage of machines and skilled mechanics.

Prominent among these materials are the sintered tungsten carbides and the cobalt super high speed steels. The carbide cutting material was developed in Germany immediately following the World War, and its generous use has been a major factor in that country's unprecedented armament program, carried out with machining equipment probably inferior to our own. Productivity of both machines and operators was multiplied by the fullest use of the fast cutting carbide tools.

The use of sintered carbide tools in Europe, according to the last available pre-War information, was about ten times greater than in the United States, even though we have many more potential applications. The significance to us is that Europe, particularly Germany, secured speedy production regardless of the higher initial expense of better tooling, and despite the fact that the use of carbide tools and fast operations on older machines hastened their obsolescence.

European manufacturers also adopted the cobalt types of super high speed steel to an extent not approached in this country. Nations

which had secured this type of steel from Germany prior to the present war, turned to this country after Sept. 1, 1939, and placed orders in amounts exceeding total domestic consumption.

Our nation is now faced with the same rearmament problem that Europe had to meet. A sufficient number of new machines to do the job may not be forthcoming for months. In the shops of the nation, however, are thousands of machines which in normal times are not considered adaptable to the high speeds and stresses associated with the working of hard tough materials used in munitions manufacture. Tooled with carbides or super high speed steels, however, they can do a good job in the emergency. Since these fast cutting tools are immediately available, they can step up production immediately and partially offset the deficiency in specially designed machines.

The new tooling, moreover, would immediately increase the output of each skilled machine operator while additional personnel is being trained. Labor and industry have expressed a desire to cooperate in the interests of national defense. If each translates its patriotic intentions into practical action, there need be no serious bottleneck in machine tool operation.

DONALD G. CLARK

Arc Weldors Must Be Qualified

Special letter to METAL PROGRESS
by W. J. CHAFFEE
Sales Manager, Welder Division
The Hobart Brothers Co.

TROY, *Ohio* — That letter from JAMES F. LINCOLN entitled "No Mystery in Arc Welding" published in the April issue of METAL PROGRESS, in which he described the simplicity of the arc welding process, has created considerable discussion. You probably will be glad to present another side of what turned out to be at least one rather acrimonious argument.

There is nothing I would like better than to see the sale of arc welding equipment double or triple, year after year. I feel, however, that Mr. LINCOLN has gone too far in minimizing the importance of trained operators ("weldors").

He was undoubtedly referring to large plants that have used welding for a long time and have highly developed procedure control when he said "The only thing that a welding operator can do is to hold the end of an electrode at a certain distance above the deposited metal and advance it along the seam to be welded at a certain speed. There is nothing more than this that is involved in this operation. It is neither complicated nor difficult. As a matter of fact, with proper electrode, proper setting of the welding machine and proper preparation of the work, it is practically impossible to make a weld which will not stand up in service without having it so evident to the inspector that he would immediately reject it."

It seems to me that airplane manufacturers might just as logically advertise that "The only thing that a pilot can do is to move the stick, push the rudder bar and give the engine the gun. There is nothing more than that involved in this operation. It is neither complicated nor difficult. As a matter of fact, with proper gasoline, proper manipulation of the controls, and fair weather, it is practically impossible to arrive at the wrong destination without having it so evident that the pilot can return to his starting point and try again."

Being responsible for the distribution of a well-known line of arc welding equipment, I've been travelling about 30,000 miles annually for several years throughout the United States, Canada and Mexico, in order to get first hand information. Naturally, that has brought me into personal contact with large and small users of arc welding in various industries and I do not believe a large percentage of them would be any more willing to trust their welding to inexperienced or untrained operators than to start a flight across an ocean with an untrained pilot. (They're not always as successful as CORRIGAN!)

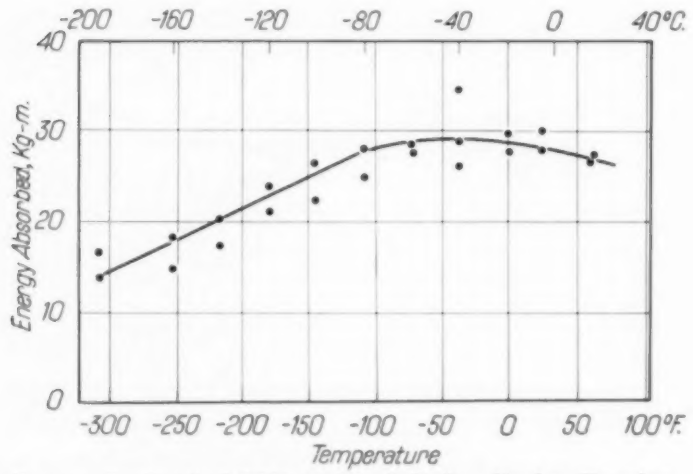
True, there have been remarkable developments and improvements during recent years with respect to equipment, methods and materials. The arc welding process has unquestionably been greatly simplified, but I do not believe this condition should be exaggerated — that anyone should be induced to adopt the process believing that it can be effectively and economically used by inexperienced or untrained personnel. Such a policy could hardly be expected to contribute to the well-being of the industry as a whole, even if it were acceptable in certain exceptional cases.

Contact with large users and with various sections of the American Welding Society has given me the impression that there is more and more attention being *(Continued on page 216)*

Brittleness of Frigid Metal

Special letter to METAL PROGRESS
by N. DAVIDENKOFF
Professor, Physico-Technical Institute

LENINGRAD, *U.S.S.R.* — The second and third phases of our studies on the impact test (in addition to the problem of high speeds discussed briefly in last month's METAL PROGRESS) are those of the critical temperature of brittleness and the mechanism of the fracture at low temperature. Some of this work was done on an impact machine for torsion tests of our own design, wherein, unlike the LUERSSEN-GREENE machine, the determination of the energy absorbed is based on the use of a ballistic disk. The specimen is twisted at the expense of the kinetic energy of a rotating fly-wheel connected to one head of the specimen; the other head is connected to a heavy disk which acquires, after the impact, a definite angular speed to be measured; the latter, at a given speed of the fly-wheel, becomes proportional to the energy absorbed.

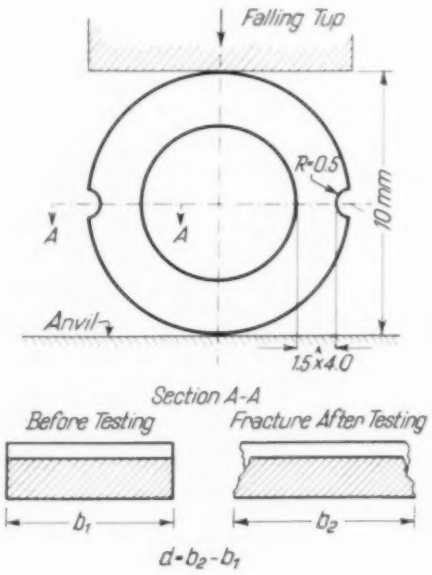


Coarse-Grained, 0.20% C Steel Fails, Under Torsion Impact, With Tough Rupture of Shearing Type, Down to the Temperature of Liquid Air, Although the Energy Absorbed Is Hardly Half That at —40° C.

From some considerations expressed in my letter to METAL PROGRESS in December 1936 on "Torsion Versus Beam Impact Test" it could be expected that when passing to torsion, the critical temperature of brittleness would considerably decrease as compared with that obtained in bending tests. This assumption is fully confirmed by experimental evidence; thus the unnotched specimens of coarse-grained steel (0.2% C) which had shown a brittle fracture at —140° C., upon impact bending, in the case of impact torsion showed a tough rupture of the shearing type even at the temperature of liquid air. At the same time a new phenomenon was observed which had been absent in the bending tests from —40° C. downwards, the energy absorbed and the angle of twist decreased continuously, retaining at —200° C., only half of their maximum value at —40°. This is shown in the curve at the left.

The question as to the connection between cold brittleness and the twinning of the ferrite was raised by HUGH O'NEILL as long ago as 1926 in the *Journal* of the Iron & Steel Institute. Both phenomena are promoted by the same conditions (low temperature, high velocity, high content of phosphorus and silicon, large crystals). It seemed thus natural to assume that the occurrence of brittleness was due to the appearance of twins. The aspect of a brittle fracture in mild steel due to impact was therefore studied microscopically by P. SACHAROW and E. SHEVANDIN. Their photographs of the fissures showed that quite a number of the adjacent grains contained twinning bands partly oriented parallel to the neighboring portion of the fissure. A steel cone was then pressed at various temperatures into the specimen of mild steel, and the cross-section through the axis of the impression was examined; twinning occurred at a temperature of —170 to —190° C., which, for the given material, coincides with the critical temperature of brittleness in the static fracture of unnotched specimens.

Twinning produced in zinc single crystals at low temperatures by stretching was also studied by A. KOLESNIKOV. Such tests always resulted in brittle fracture either along the planes limiting the twinning bands, or along the basic planes of the



Small Rings, Broken by Impact, Are Used to Give Relative Estimate of Toughness by Measuring Lateral Deformation of Fractured Surface Below Notch

twins. X-ray studies undertaken by M. JAKUTOVICH, M. MOTCHALOW and E. JAKOVLEVA showed that the maximum distortion of the lattice occurs at the boundary between the twin and the initial crystal. In view of the above it may be inferred that, in spite of any appearances to the contrary, the cold brittleness of iron is not an ideal brittle fracture; the phenomenon starts with the formation of twins, after which the ferrite crystals are broken either along these twins or along their own cubic planes.

We made an attempt to devise as simple a method as possible, requiring a minimum of material and preparation, so ordinary control laboratories could readily make tests at gradually decreasing temperatures, and so determine the critical temperature of brittleness. For this purpose the author suggested small ring-shaped specimens with two notches, as shown in the second drawing. This ring would be flattened by the falling hammer of an impact machine. Instead of determining the energy absorbed, the "lateral deformation" *d* at the base of the fracture was measured by means of a microscope. The ring-shaped specimens were cooled in a small bath with liquid air and placed on the anvil; the temperature was measured with a thermocouple welded to the specimen. Several specimens were placed into the bath simultaneously, and they were broken one after another at gradually rising temperatures.

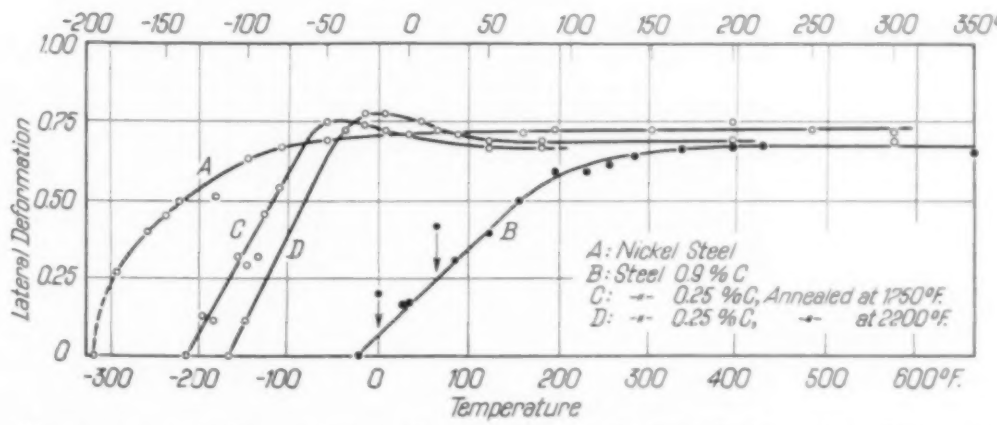
Curves obtained in this way by E. SHEVANDIN give a clear picture of the cold brittleness of several materials. Although in their upper part these curves differ somewhat from those obtained with the usual MESNAGER-CHARPY specimens (owing to the deformation being less pronounced, the upper limit of the critical interval is displaced towards low temperatures), still they prove quite adequate for comparative estimations. At the same time, the small dimensions of the specimens allow of use for such special tests when only a limited quantity of the material is available. N. DAVIDENKOFF

Nitrogen Is the "Carbon" of Ferritic Steels

Special letter to METAL PROGRESS
by ALBERT M. PORTEVIN
Editor, La Revue de Métallurgie

PARIS, *France* — When the percentage of chromium or other elements which form a so-called gamma loop in steel, such as aluminum or silicon, becomes sufficiently high in relation to the carbon content, a ferritic steel or alloy is obtained that is devoid of transformation points and in which the austenitic state cannot be attained by heating. These elements might therefore be properly called "alpha formers" or "alphagenous elements". As a consequence, such steels are unsuitable for martensitic quenching and structural refining heat treatments. This may be a serious drawback from the standpoint of mechanical properties such as ductility and tensile strength; in the as-cast or superheated condition they are coarse grained and consequently brittle, and nothing much can be done about it in the way of a regenerative heat treatment. Furthermore, they cannot be given the properties obtained by quenching and tempering the true steels that are austenitic at high temperature.

These valuable properties may be recaptured by introducing nitrogen. It is fortunate that the presence of chromium considerably facilitates the absorption of this element. It may be added by melting in nitrogen (according to KRIVOBOK), from the air (ADCOCK), or by the electric arc (PORTEVIN and SÉFÉRIAN) because of the presence of atomic nitrogen. This element may also be introduced by means of products previously nitrided, for instance ferrochromium (RUS-



Changes in the Impact Strength (Really, the Lateral Deformation Below the Notch) of Ring Specimens of Various Steels, Tested at Various Temperatures

SELL FRANKS) or ferrotitanium (COMSTOCK).

The structure of castings has been refined by such nitrided additions and ferritic steels have been made hardenable by a nitrogen content at least equal to a hundredth part of the chromium content (FRANKS, NORWOOD, and COLBECK and GARNER).

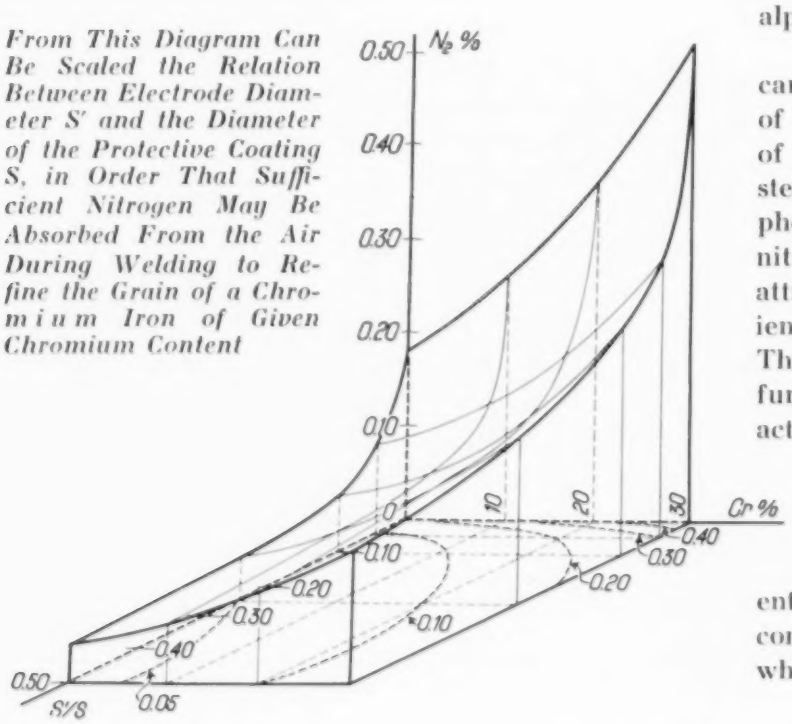
Hardening of Chromium-Iron Alloys by Nitrogen

CHEMICAL ANALYSIS				QUENCHED IN WATER FROM 2100° F.		TEMPERED AT 1500° F. AFTER QUENCHING	
C	N_2	Cr	O_2	BRINELL HARDNESS	TOUGHNESS (a)	BRINELL HARDNESS	TOUGHNESS (a)
0.035	0.02	16.9	0.02	200	0.5	110	20
0.20	0.02	17.0	0.03	320	0.6	160	12
0.06	0.20	17.4	0.03	330	0.3	150	13.6
0.20	0.20	17.4	0.01	440	0.4	175	7.5
0.30	0.25	17.4	0.01	481	0.3	180	10

(a) Mesnager impact strength in kg-m. per sq.cm.

Often, however, it is not necessary to resort to such additions, since the nitrogen is so easily absorbed by high chromium steels; thus, steels simply melted in a high frequency furnace contain quantities of nitrogen (0.15% N for 30% Cr steels). Now, this 0.15% of nitrogen, often neglected in ordinary analyses, is of more importance than the 0.05 to 0.10% of carbon which is added so carefully, since the nitrogen promotes hardenability just as well as carbon. Some results are given in the table, above, from which it can be seen that, in these high chromium steels, carbon and nitrogen are equally effective hardeners. Moreover, the micrographic study of quenched samples at various temperatures shows constituents which we have named, by analogy, nitro-austenite, nitro-martensite, and nitro-troostite.

A problem identical to that of refining the grain of cast steels is the problem of welding, the melted zone being similar to a coarse-grained cast steel. But here, as we showed with D. SÉFÉRIAN, good use may be made of the absorption of nitrogen by welding with the electric arc, and regulating the nitrogen content by the thickness of the electrode coating in accordance with the chromium content. The accompanying figure gives the nitrogen content in the weld metal as a function of the chromium content and of the relationship $S' \div S$ — the cross-section of the core of the electrode to the cross-section of the coating. In this way we easily obtain fine-grained, ductile welds in ferritic chromium steels, without the necessity of resorting to special additions rich in nitrogen.



From This Diagram Can Be Scaled the Relation Between Electrode Diameter S' and the Diameter of the Protective Coating S, in Order That Sufficient Nitrogen May Be Absorbed From the Air During Welding to Refine the Grain of a Chromium Iron of Given Chromium Content

Nitrogen contained in ordinary extra mild carbon steels is much lower, although it depends somewhat upon the method of manufacture. The very low carbon steels do not harden in any important degree by martensitic quenching; this is replaced by structural hardening or age hardening phenomena resulting from the variation of solubility of nitride or carbide in the alpha phase.

In this respect, the parallelism between carbon and nitrogen is apparent, but the effects of nitrogen are even more analogous to those of phosphorus. Thus, in extra mild Thomas steels (basic bessemer) which are richer in both phosphorus (from the raw material) and in nitrogen (because of the air blow) some people attribute to the nitrogen a part of the inconveniences for which the phosphorus is responsible. They would refine such steel in the electric furnace, and eliminate nitrogen by a stirring action, either mechanical or by causing the bath to boil by oxidation after having recarburized it up to 0.2 to 0.3% carbon.

But in any event, this effect of nitrogen in the refining operation is less apparent in the higher carbon steels and cannot be compared to the more active effect of oxygen, which must be kept as low as possible.

ALBERT M. PORTEVIN

The Voice with a Smile

"We hold," says a well-known writer, "that the young ladies of the American long distance telephone wires make up what is probably the most efficient public service crew in the world. They have profound patience and that capacity for taking pains that some one once said is all that genius amounts to.

"We once called a fellow at a hotel in Philadelphia but he had just departed on an automobile trip in a westerly direction. A few days later the long distance operator caught up with him in a little town in Missouri and he was the most surprised man in all but one of the States of the Union. The exception was New York. We were the most surprised there. To this day we have no idea how the operator did it."

DAMON RUNYON
in the *New York Mirror*

BELL TELEPHONE SYSTEM

The Bell System cordially invites you to visit its exhibits at the New York World's Fair and the Golden Gate International Exposition, San Francisco.

PERSONALS

John C. Sproul is now working in the tool design department of Fairbanks, Morse & Co., Beloit (Wis.) Works.

Ralph E. Herzler, University of Illinois, '40, has a position in the metallurgical department, fabricating division, Aluminum Co. of America, Massena, N. Y.

John Gadzuk has transferred from the U. S. Navy Yard in Brooklyn, N. Y., to the U. S. Navy Yard in Philadelphia as an assistant marine engineer in the industrial department.

A. J. Dornblatt formerly senior research associate, American Silver Producers Research Project, is now engaged in process development and research at the research laboratory of Crown Cork and Seal Co. in Baltimore.

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Warehouses in Principal Industrial Centers

Paul T. Dowling, Missouri School of Mines and Metallurgy, '40, is employed as an inspector in the metallurgical department of the Aliquippa Works, Jones & Laughlin Steel Corp.

Paul G. Nelson, chemical engineer, University of Cincinnati, '40, is now employed at the metallurgical laboratory of Republic Steel Corp., Canton, Ohio.

R. Isenbarger, M.S. Purdue University, '40, has a position as metallurgist with the Dallas Division of Revere Copper & Brass, Inc.

Roscoe R. Hershey, B.S. in metallurgical engineering, Ohio State University, '40, is working in the Steel and Tube Division of Timken Roller Bearing Co., at Canton, Ohio.

Norbert Polakowski, Michigan College of Mining and Technology, '40, is now metallurgist with Reynolds Metals Co., Louisville, Ky.

Kurt R. Mattson, B.S. in metallurgical engineering, Michigan College of Mining and Technology, '40, is a metallurgical inspector at Inland Steel Co., East Chicago, Ind.

Cecil J. Bier, Carnegie Institute of Technology, '40, is research metallurgist for McKenna Metals Co., Latrobe, Pa.

Fred L. Plummer, chief design engineer on the Cleveland Main Avenue Bridge, is now chief research engineer for Hammond Iron Works, Warren, Pa.

Awarded the 1940 Proctor Memorial Award of the American Electroplaters' Society: **Carl A. Zapffe** and **Charles L. Faust**, metallurgist and chemical engineer, respectively, Battelle Memorial Institute, Columbus, Ohio.

C. E. Spragg has been transferred from the New York office of Jessop Steel Co. to the Boston district, with headquarters in Hartford, Conn.

MEETING A SERVICE CHALLENGE

Coal mine shaker conveyors work in cramped quarters. If a conveyor fails, everything stops until repairs or replacements are made. So conveyors must be capable of continuous operation.

One manufacturer now meets the challenge by using Chromium-Molybdenum (SAE 4140) Steel for the all-important crank shafts of his shaker conveyors.

When properly heat treated, the steel develops good tensile and fatigue strength in the 5¾" section used, together with adequate hardness. Conveyor crank shafts made of this steel are achieving remarkable service records.

If anywhere in your product there is a part which presents special difficulties it may likewise pay you to investigate the possibilities of Molybdenum steels. Complete data will be found in our technical book, "Molybdenum in Steel," which is sent free to interested production executives and engineers on request.

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MOLY

PERSONALS

Barrett L. Taft is now metallurgist in the materials laboratory of Pratt & Whitney Aircraft Division of United Aircraft Corp.

Samuel Dinerstein, formerly chief chemist and metallurgist for the Waltham Watch Co., is now chief metallurgist for the Thomas B. Gibbs & Co., Delavan, Wis.

Matt Meinen is now electric furnace superintendent with the Crucible Steel Co., Midland, Pa.

Transferred by Electro Metallurgical Co.: **Frederick W. Hanson**, metallurgist, from the Pittsburgh to the Birmingham office.

James A. Kavenaugh has resigned from Carnegie-Illinois Steel Corp. to become junior metallurgist at the Naval Aircraft Factory in Philadelphia.

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Carburizing and heat-treating equipment manufactured by The Pressed Steel Company will give longer service, with the weight as low as one-third less that of cast alloy.

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Photograph of an Annealing Cover used in Steel Mills. Made of Alloys to suit your specifications. Any size. Any shape.

Photograph of recent shipment of Annealing Tubes. They are 20 ft. long, 12 inches in diameter with 1-4 inch wall. Made to your specifications.

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F. H. Pennell, formerly with Wyckoff Drawn Steel Co., is now metallurgist, De Laval Steam Turbine Co., Trenton, N. J.

Transferred: **Edwin C. Ludwig** from metallurgical engineer of National Bearing Metals Corp., St. Louis, to manager of the company's Chicago plant.

Charles Lee Clayton, formerly standard practice writer in the wire and nail mill, Pittsburgh Works, has been made alloy and stainless steel clerk to the assistant general manager of sales, Columbia Steel Co., San Francisco.

George L. Mitsch is now employed in the metallurgical laboratory, American Car and Foundry Co., Berwick, Pa.

H. P. Bristol, vice-chairman, New Haven Chapter, formerly president, The Bristol Co., is now sales engineer for Crucible Steel Co. of America in New Haven. **M. Churchelow** is now president of The Bristol Co.

Paul D. Merica, vice-president, International Nickel Co., has been awarded the platinum medal for 1940 of the British Institute of Metals in recognition of his services to metallurgy. He is also one of the newly elected members of the executive committee, American Society for Testing Materials.

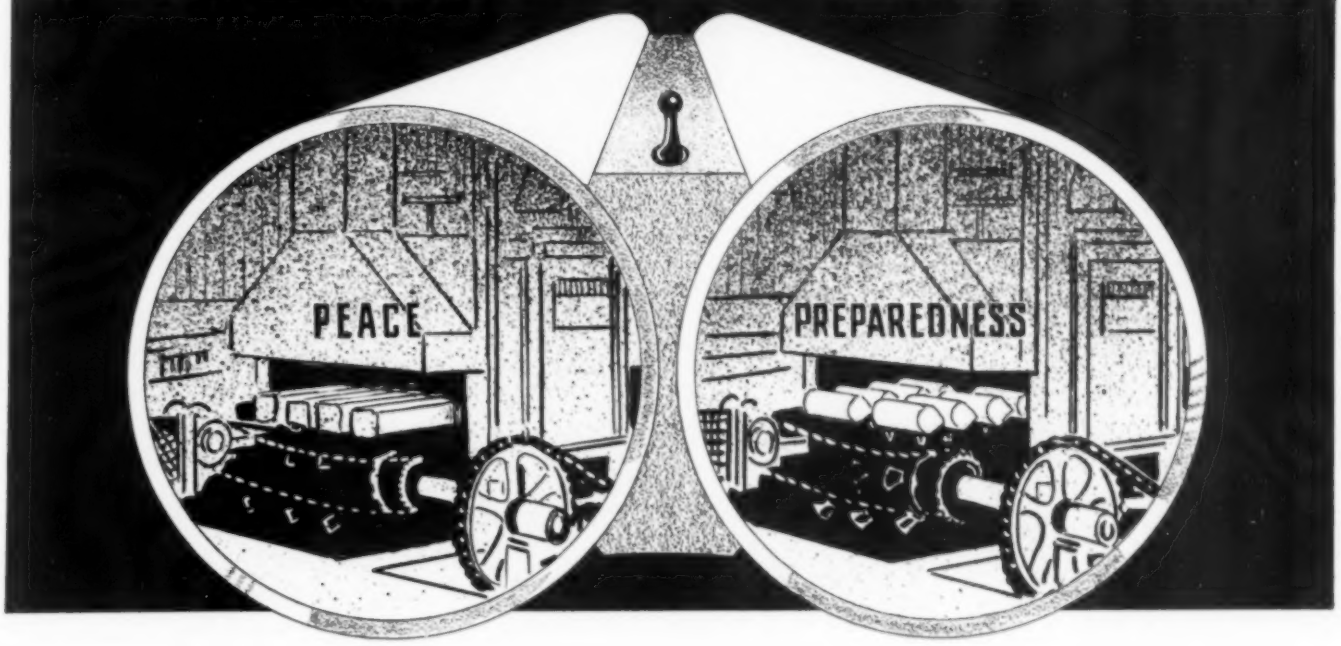
J. S. Billingsley has been appointed manager of the Pittsburgh branch of Crucible Steel Co. of America.

Appointed metallurgical engineer of the Copper Iron and Steel Development Association, Cleveland: **J. Eugene Jackson**, formerly with the Chase Brass and Copper Co., Cleveland.

Harry D. McKinney has been made vice-president in charge of manufacturing operations, Driver-Harris Co., Harrison, N. J.

A. E. Pavlish is now chief chemist at Universal-Cyclops Steel Corp., Bridgeville, Pa.

A DOUBLE-BARRELED HEAT TREATING FURNACE



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Manganese Steels

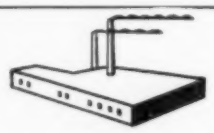
(Starts on page 163)

Chromium - manganese - silicon steels are also used for the largest size forgings (up to 12 in. diameter). The analysis quoted by KALLEN and MEYER is considerably higher in alloy than the "cromansil" steels promoted in America, being 0.40% carbon, 1.10% chromium, 1.40% manganese and 1.0% silicon. Typical tensile properties are 100,000 psi. yield, 135,000 psi. ultimate, 11% elongation and 50% reduction of area. This comparatively low elongation figure, if regarded as dangerous in the intended use, will cause the German metallurgist to turn to a manganese-vanadium steel of about the same carbon content and a little higher manganese. The well-known influence of vanadium in raising the yield point, increasing the depth of hardening, and refining the grain is clearly shown. A detailed investigation of a crankshaft made of one of these steels showed good properties throughout, uniform in the results both of longitudinal and of transverse tensile and impact test pieces.

The pearlite transformation in carbon-manganese steels is fastest at 1100° F.; the intermediate stage (to an acicular structure) at 800° F. Martensite forms in a rapidly cooled steel at temperatures which vary with (are reduced by) both the carbon and manganese content.

It is claimed by the German authors that there is at the disposal of the steel maker a variety of manganese and silicon steels which, within the range of tensile strength 90,000 to 160,000 psi., show good yield points and acceptable values of elongation, reduction of area, and impact. Such steels, it is held, are suitable substitutes for the chromium-molybdenum steels conforming to the old German specification. (Neither mass effect nor temper brittleness are discussed, on both of which the presence of molybdenum is salutary.)

The properties of all the steels described are well known and some of them have received wide application in England. The addition of silicon and of chromium to manganese steels is, however, not generally regarded as a desirable way of improving the properties of manganese steels for constructional purposes. High silicon steels are more likely to show banding and inferior transverse properties. Manganese-chromium steels are more liable to non-uniformity of properties as a result of variations in the rate of cooling than manganese-nickel steels, and it would appear that manganese-molybdenum steels offer undoubted advantages over all those described. However, when necessary the high manganese steels with suitable careful treatment are being successfully applied for many purposes.



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1—100 KW—200 lb. furnace for melting pure nickel in the manufacture of nickel anodes.
1—125 KW—350 lb. furnace for melting brass and bronze alloys in jobbing work.
1—30 KW—50 lb. furnace for melting high speed tool steel and special cutting alloys.
1—175 KW—500 lb. furnace for melting alloy gray irons and white iron for short cycle malleable and special heat treated irons.
1—125 KW—350 lb. furnace for general plant maintenance castings.
1—125 KW—350 lb. furnace for experimental and research work.

Additional Detroit Electric Furnace installations being made at the present time include furnaces in plumbing goods plants, a valve foundry, arsenal and naval installations and jobbing foundries for producing ferrous and non-ferrous specialty castings of superior quality.

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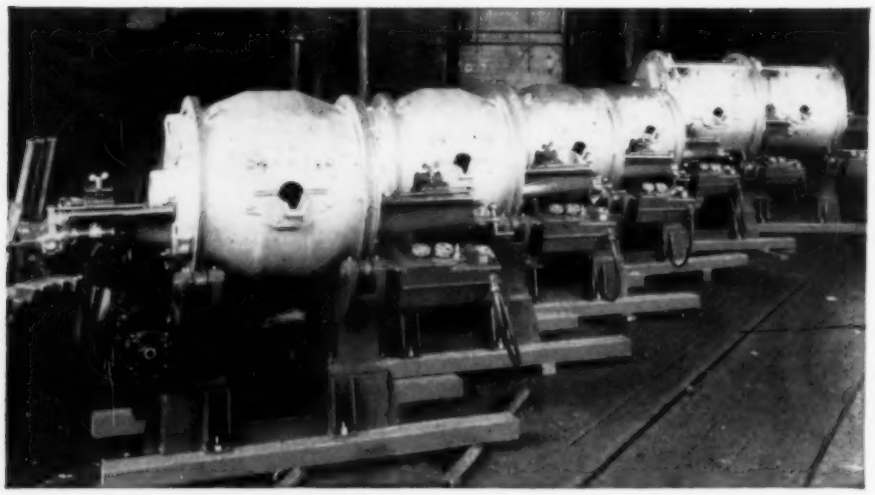

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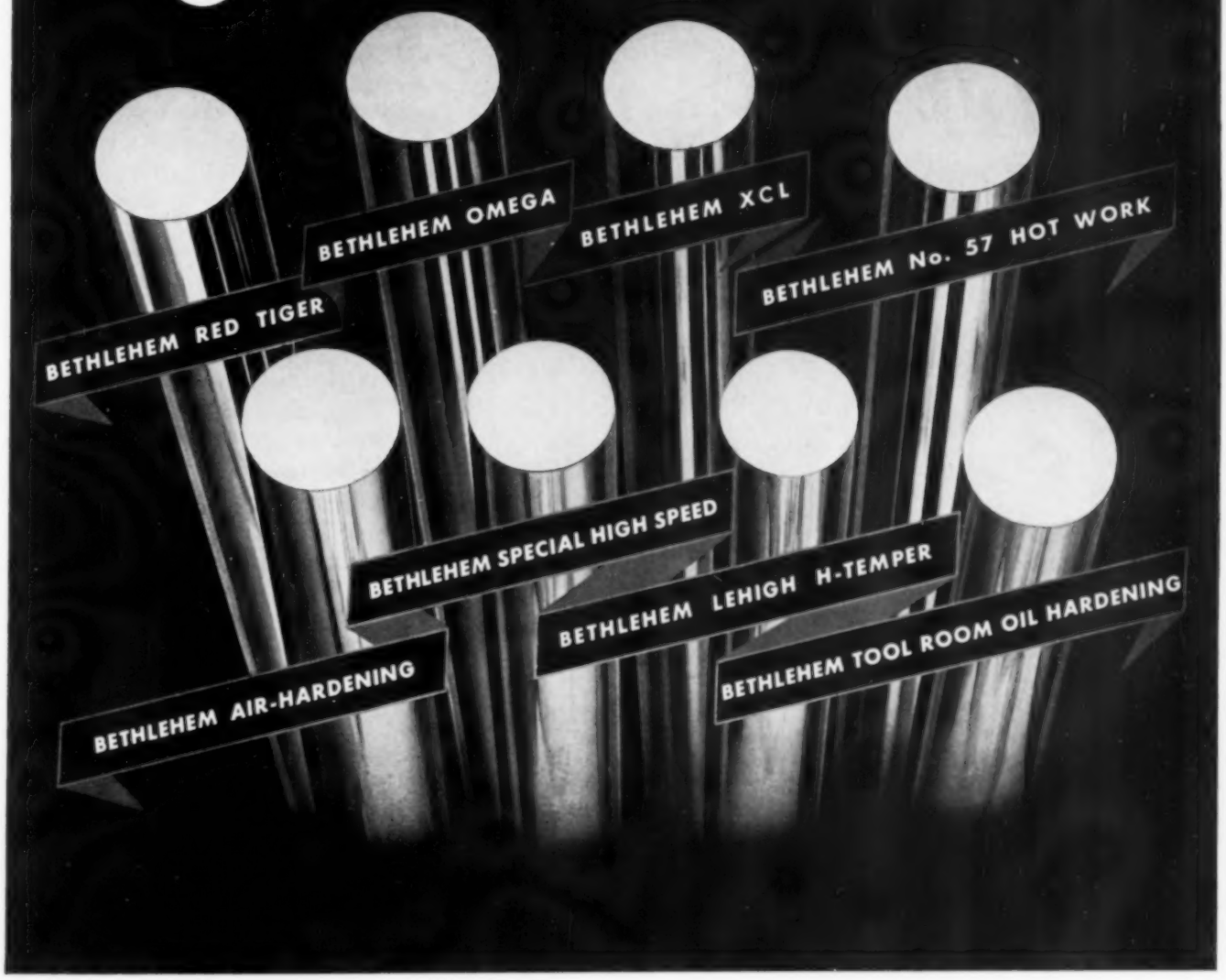

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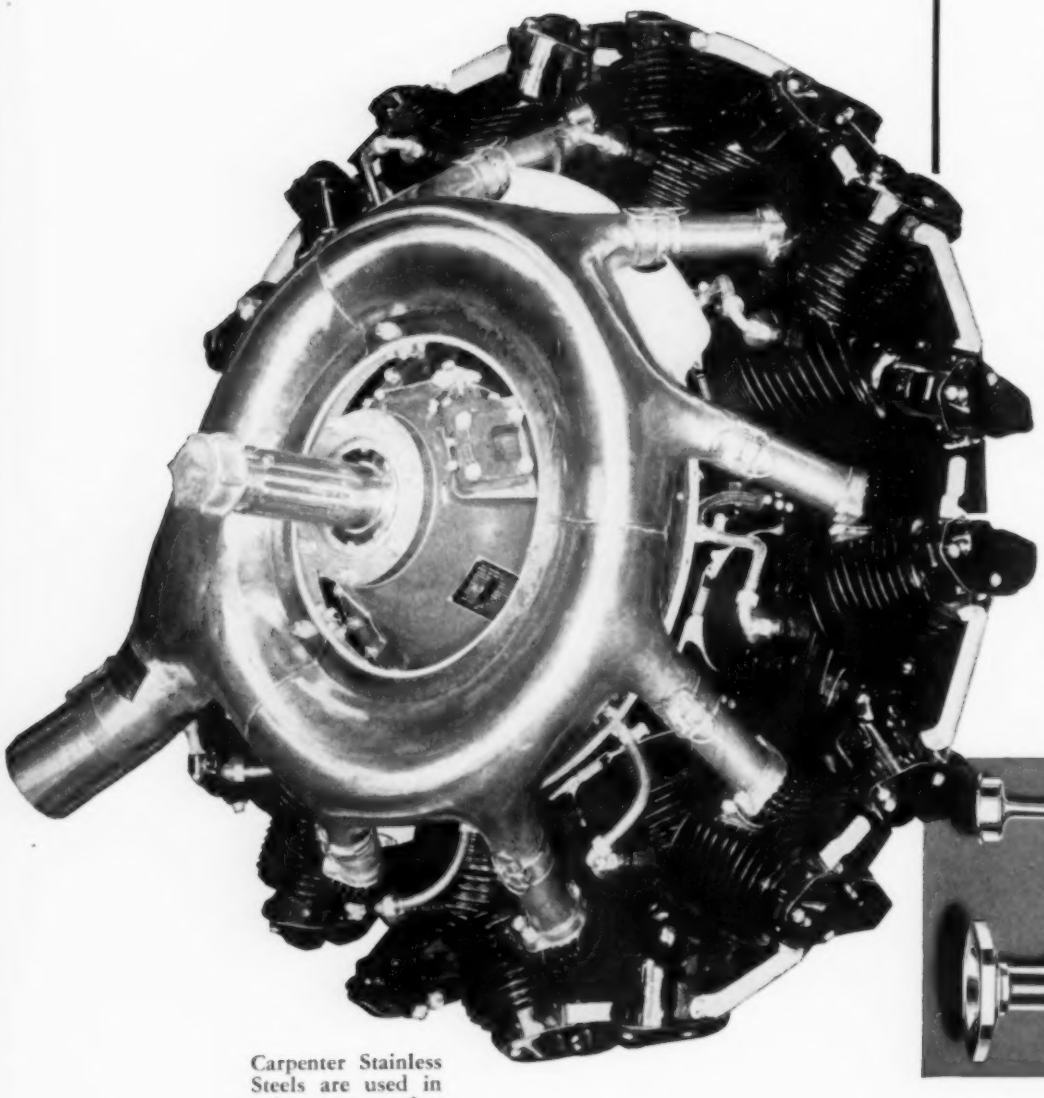
Why *Carpenter* Stainless for



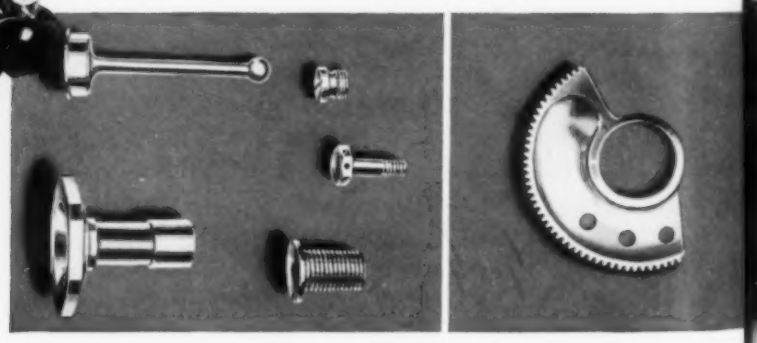
Carpenter Stainless Steels are used in valve seats, carburetor air intake screens, butterfly valves, cotterpins and inserts. In some models, valves and exhaust manifold nipples are also made from stainless.

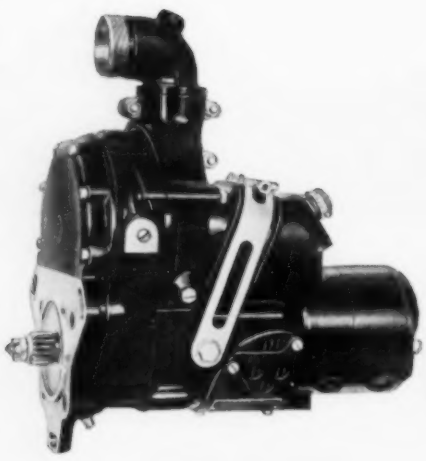
FASTER PRODUCTION? Yes! That is one reason. Carpenter Free-Machining Stainless and Carpenter's clean blanking, easy forming Stainless Strip *are* close to mild steel as far as production *speed* is concerned.

LOWER COST? Yes! That is another reason. Lower unit costs are only natural when production speeds are higher, interruptions fewer. But—

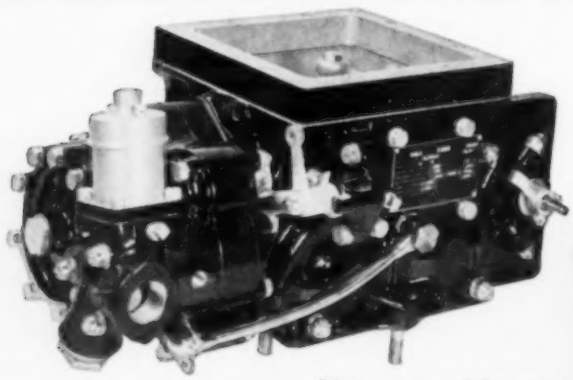
THE BIG REASON GOES BEYOND FASTER PRODUCTION AND LOWER UNIT COSTS. Where safety is paramount—where performance is all important—where the reputation of a product is at stake—the vital thing is the dependability of Carpenter Stainless Steels. Their extreme uniformity, their controlled temper, gauge, color and physical properties. Their ability to go through inspection with a minimum of rejections.

Manufacturers and pilots alike feel confident in the performance of Carpenter Stainless Steels in corrosion and heat resistance applications on





In these latest type aircraft magnetos, stainless steel is used for the rotating magnet shaft and for some of the holding screws.



Ninety-two stainless parts in this carburetor—many of them of Carpenter Free-Machining grades.

Vital Parts?

airplanes. Made and inspected in the way you yourself would do it, stainless parts made from these steels are fast and easy to produce, safe in flight, serviceable after years of use. There is evidence to spare in the illustrations on these pages of the wide use of Carpenter Stainless for vital aircraft parts.

So if it's to be made from STAINLESS, come to the company that pioneered easier-to-work stainless steels. Your Carpenter representative will work with you to select the best and most effective grade, most perfectly suited to service requirements. As an extra bonus, you will gain smooth, fast, low cost production of stainless parts for every type of product. Call your Carpenter representative by 'phone today.

THE CARPENTER STEEL COMPANY
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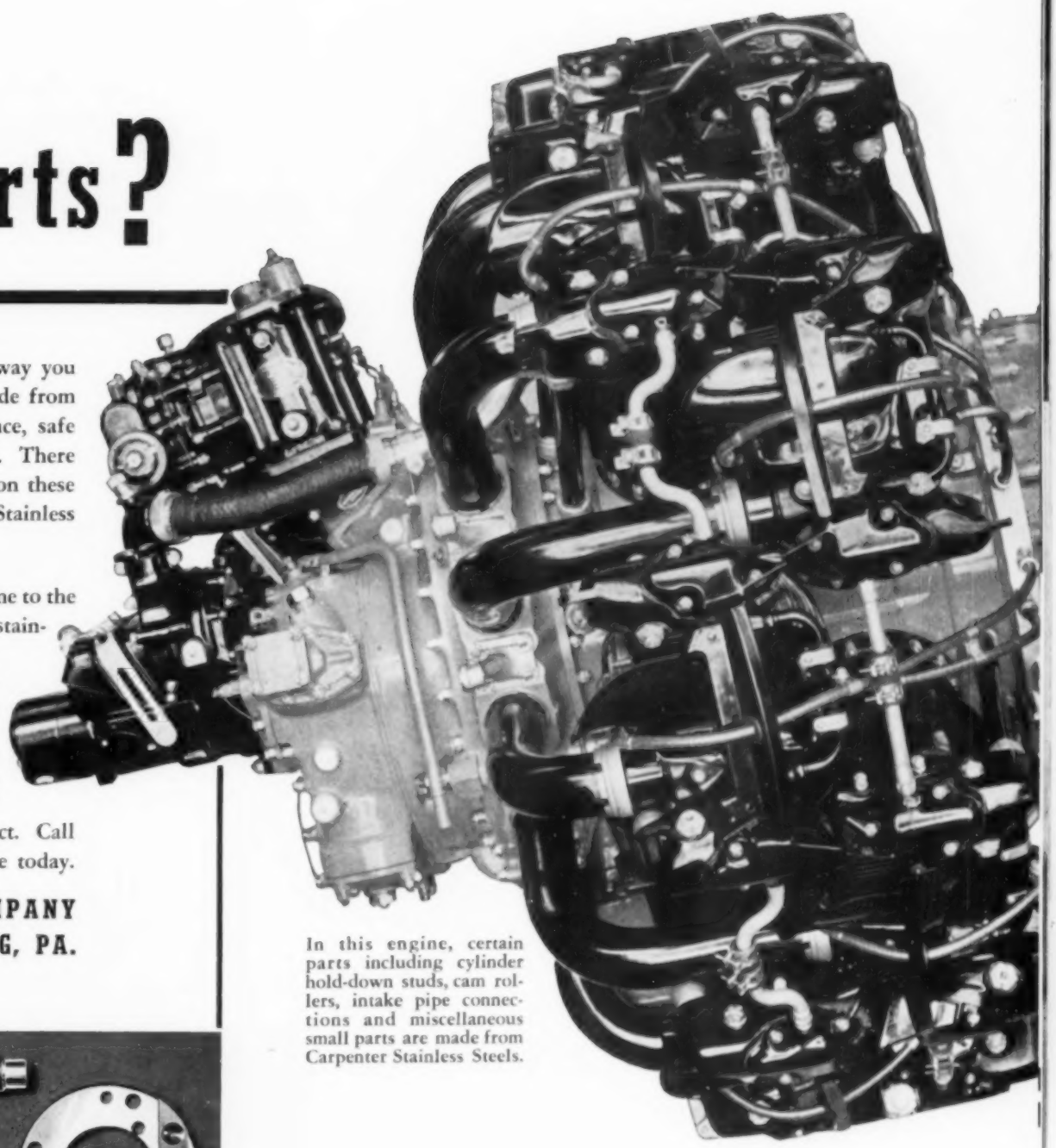
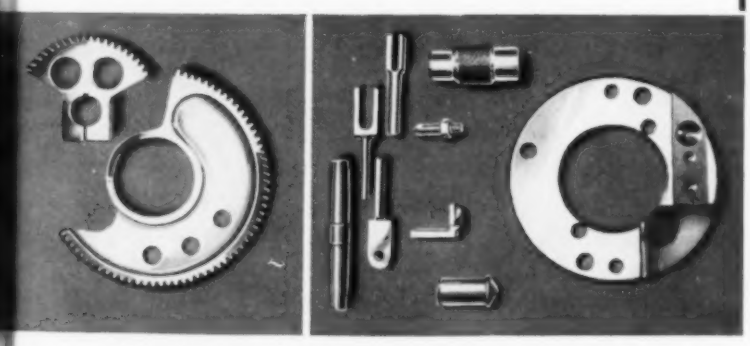
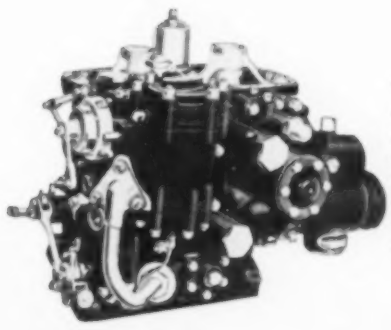


In this engine, certain parts including cylinder hold-down studs, cam rollers, intake pipe connections and miscellaneous small parts are made from Carpenter Stainless Steels.



Distributor and carburetor parts, control fittings, etc. made from Carpenter Stainless Steels for aircraft use.

more than corrosion resistance



"This aircraft carburetor utilizes Carpenter Stainless Steel for a number of internal and external parts where the non-corrosive and fine wearing qualities of this steel make its use essential."

Carpenter STAINLESS STEELS

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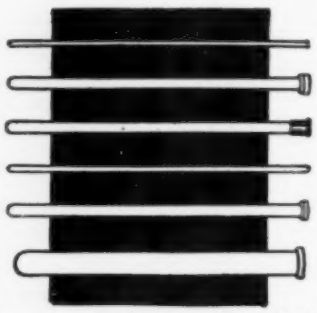
THERMOCOUPLES AND ACCESSORIES



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NEW BEARING

(Starts on page 173) pletely immersed in the babbitt bath, the second is the vacuum chamber, and the third is the sizing and cooling stage. The machine holds 10,000 lb. of high-lead babbitt at a precise temperature. Molten metal in the first stage is held to a definite level by well known expedients. This serves to seal the passage and also to preheat the entering strip.

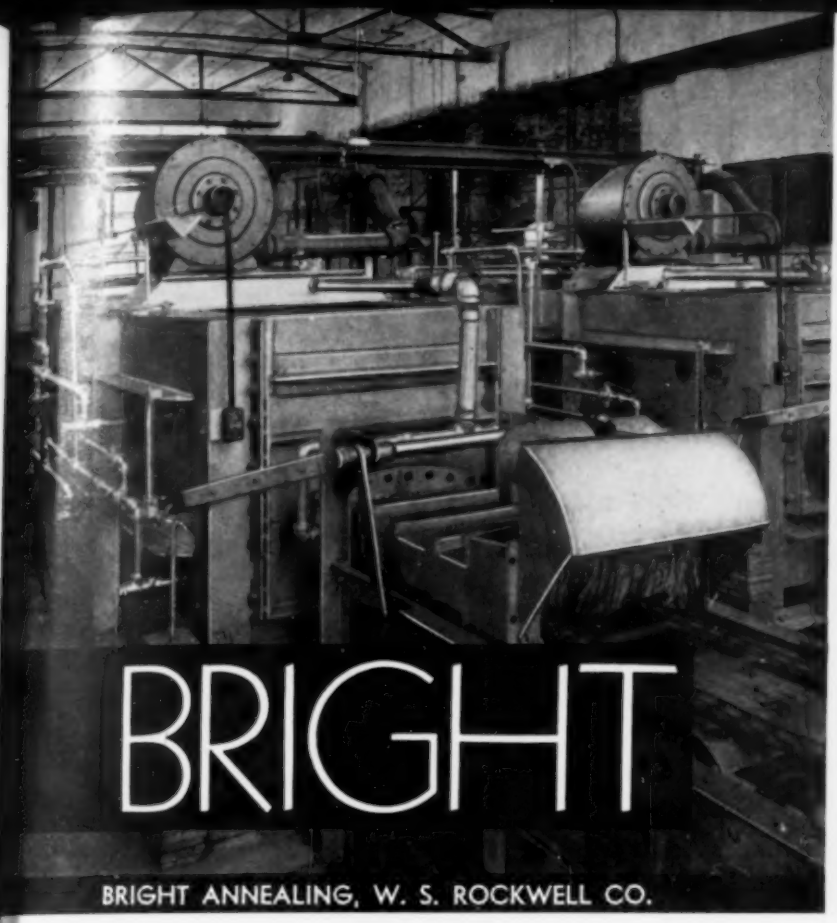
The second or vacuum stage is really the heart of the whole device. The chamber is completely sealed by the molten babbitt. In addition, the lower end at the center has a definite barometric head due to the volume of liquid in the system. The actual value of the vacuum in the chamber is maintained at from 6 to 7 mm. of mercury. Its function is to evacuate all of the voids of the porous matrix, and enable the babbitt to reach every portion of the spongy structure.

At the third or exit stage, there is a clever mechanism for maintaining the thickness of the babbitt within the desired limits. Simultaneously the molten bearing metal is "frozen" to its desired grain size by rapid chilling with jets of cold water.

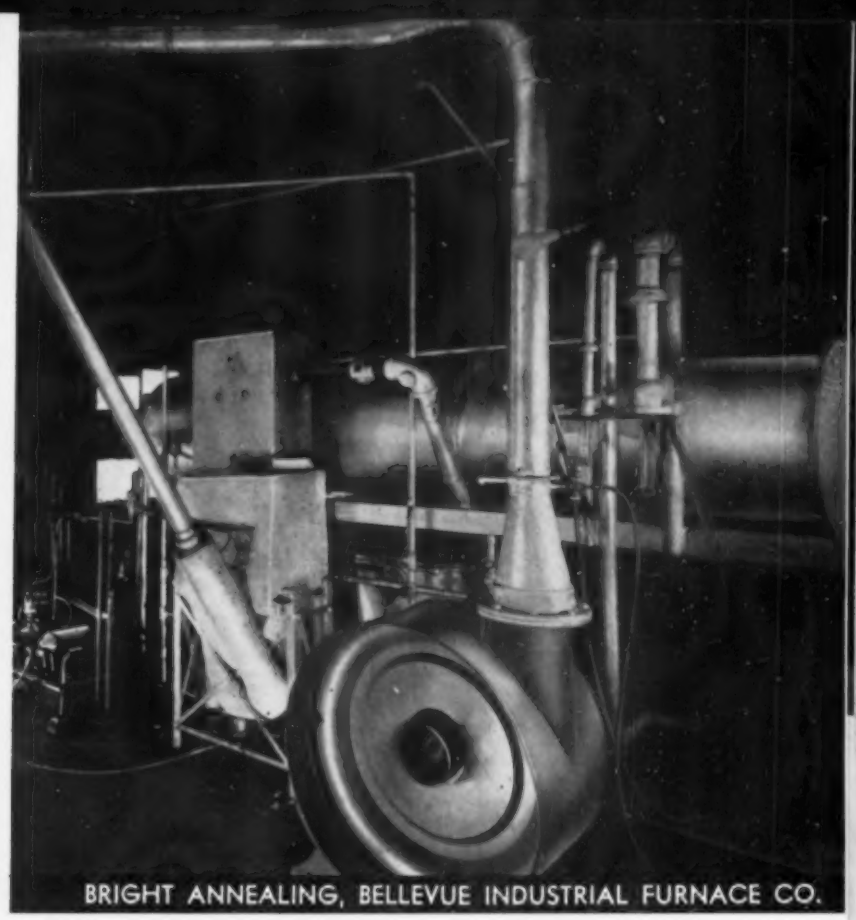
From the babbitting machine, the strip goes to a milling machine fitted with pinch rolls to impress a positive tension on the strip. The milling machine is fitted with two large milling cutters — the first a conventional down-cut, the second taking a climb cut. This operation removes sufficient babbitt to produce the desired total thickness of the strip, from the under side of the steel back to the top of the bearing metal surface. Sufficient stock is left to provide an average of 0.005 to 0.010 in. excess metal for final finishing operations.

Final stage on this line is a stamping and blanking press which cuts the strip into blanks of the right size for the forming of the half-shell. The remaining operations are found to be conventional bearing practice and need but little discussion. Touching only the high-spots of the finishing operations, it is noted that the blanks are formed into half-shells, chamfered, and broached individually in preparation for finish-broaching.

The parts now are tinplated all over, finish-broached to a fine burnished finish. Each of the broaching operations is checked for precise tolerances as to thickness and fit within a master gage.



BRIGHT ANNEALING, W. S. ROCKWELL CO.



BRIGHT ANNEALING, BELLEVUE INDUSTRIAL FURNACE CO.

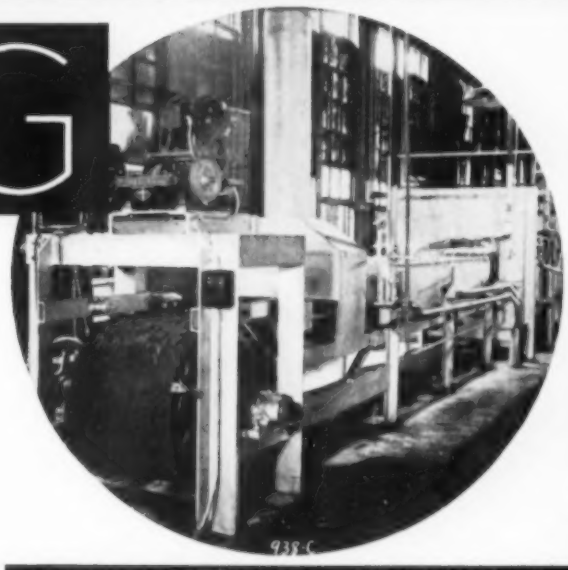
BRIGHT ANNEALING

The satisfactory performance of annealing furnaces depends on close regulation and a steady air supply. Here heating and cooling rates may be as important as actual processing temperatures in their effect on product uniformity, so that a smooth, staight-line-controllable air supply is essential to a quality job. Bright-annealing with the products of combustion as the protective atmosphere can obviously be successful only with a completely dependable combustion-air supply.

Spencer Turbo-Compressors inherently deliver a constant pressure throughout the range of each machine. No automatic control device is necessary. Air delivery is smooth, continuous, clean and dry.

Your equipment manufacturer will tell you a dozen other reasons why Spencer Turbos are the accepted standard for gas and oil-fired equipment.

ASK HIM FOR THE SPENCER TURBO BULLETINS



938-C

CLEAN ANNEALING, SURFACE COMBUSTION CORPORATION

BRIGHT ANNEALING, AMERICAN GAS FURNACE CO.

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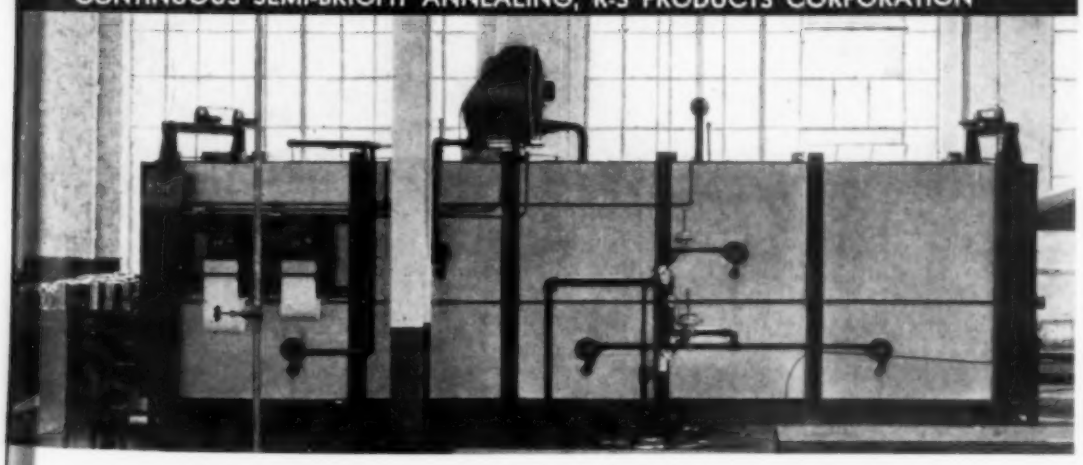

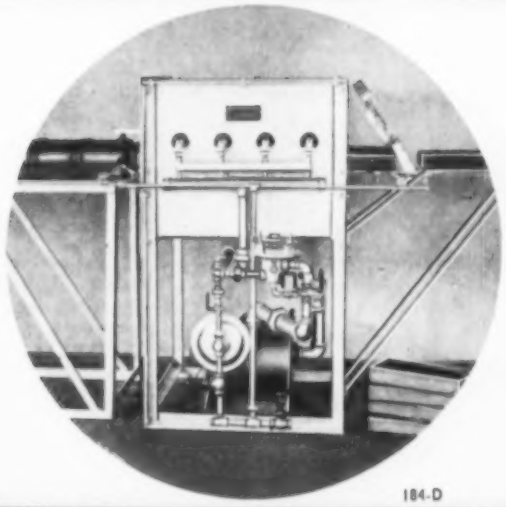

184-D

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Send information on the new Holden Pot Furnace

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CRACK STRENGTH

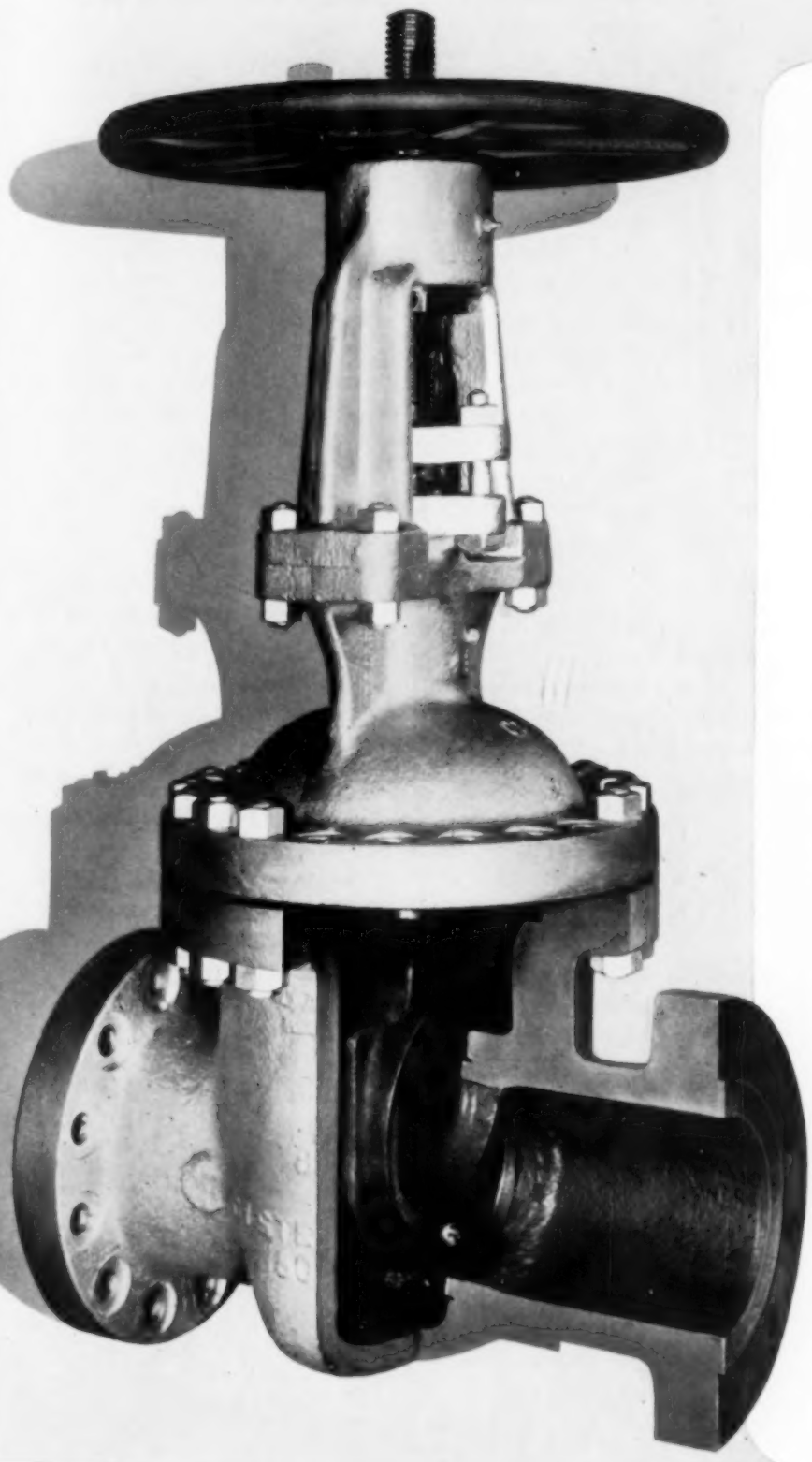
(Continued from page 182) This cohesive strength is greater than the technical cohesive strength determined with a sharp notch. Whether KUNTZE's cohesive strength really corresponds to the value of the "hydrostatic tension stress" at which fracture would occur in the absence of defects is a subject that is not under discussion. It certainly is not the crack strength for a very deep crack.

To recapitulate, sharp notches cannot be used (with notch sensitive materials) to measure KUNTZE's true cohesive strength. The static crack strength, which I have tried to measure, is an altogether different quantity and requires for its measurement sharp notches. I have been able to get more reproducible results with filed notches and still better with specimens containing fatigue cracks than with specimens machined following KUNTZE's instructions in *"Kohäsionsfestigkeit"*.

As to the freedom from bending stresses secured by the use of an alignment sleeve: I have had considerable experience with small tensile specimens (unnotched), tested in self aligning specimen holders of the type used by KUNTZE and have not been pleased with the results (testing for alignment by using several TUCKERMAN optical extensometers placed around the specimen). I may be wrong, but I am inclined to place more reliance on the alignment sleeve with straight specimens than on the other devices. I think the reproducibility of our results indicates satisfactory performance of this equipment.

I think, too, that some of the results given in the last paragraph are abnormally low and might show up in a tensile test; admittedly an extreme instance was chosen to illustrate how widely divergent the static crack strength values might be in steel of the same hardness. But I suspect that serious differences might exist without what would ordinarily be considered important differences in tensile properties. The reason this paper appeared in METAL PROGRESS and not as a technical paper to the ASM is that I do not have sufficient data to bolster a claim that the static crack strength is worth measuring, but I thought it worth bringing to the attention of the readers of METAL PROGRESS in the hope that others would apply the test and data might begin to accumulate. As to the possibility of the technical cohesive strength lying below the yield strength, it is true that KUNTZE's cohesive strength could not, but I don't see how it can be argued that the crack strength cannot, especially in view of the fact that quenched and tempered specimens undoubtedly contain residual stresses that may be quite great

VALVES ARE BETTER



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● Telebrineller is held with head against surface to be tested. Hammer blow makes impression on it and instrument bar.

MEASURING IMPRESSION
● Telebrineller Microscope is used to measure impression and computer furnished gives accurate brinell hardness of casting surface tested.

WRITE for descriptive folder

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PHONE WABash 9368

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CONTRIBUTORS

HORACE C. KNERR is president and general manager of Metlab Co. (Metallurgical Laboratories, Inc.) which he founded in 1928. With the exception of a period from 1918 to 1925 when he was chief metallurgist, U. S. Naval Aircraft Factory, most of his career has been as consulting metallurgist to various firms including Wright Aeronautical Corp., Summerill Tubing Co., Ajax Electrothermic Corp., Bureau of Aeronautics of the Navy Department, and Steel and Tubes Division of Republic Steel Corp. Mr. KNERR has won considerable fame, particularly among members of the Philadelphia Chapter ASM (of which he is a past chairman) as director of the evening metallurgy course conducted at Temple University in cooperation with the Philadelphia Chapter. He is likewise the author of a text entitled "Heat Treatment and Metallography of Steel".

ASM ASM ASM

Inspection and investigational work in both the steel works and finishing department of Jones & Laughlin Steel Corp. provided E. M. SCHROCK with a practical background and working knowledge of plant operations. This was supplemented by statistical training at University of Pittsburgh, which ably qualified him for his present position as supervisor of the statistical division of the metallurgical department at Jones and Laughlin's Aliquippa Works. His article on page 153 explains very lucidly how his department operates and how its methods can be applied to both large and small operations.

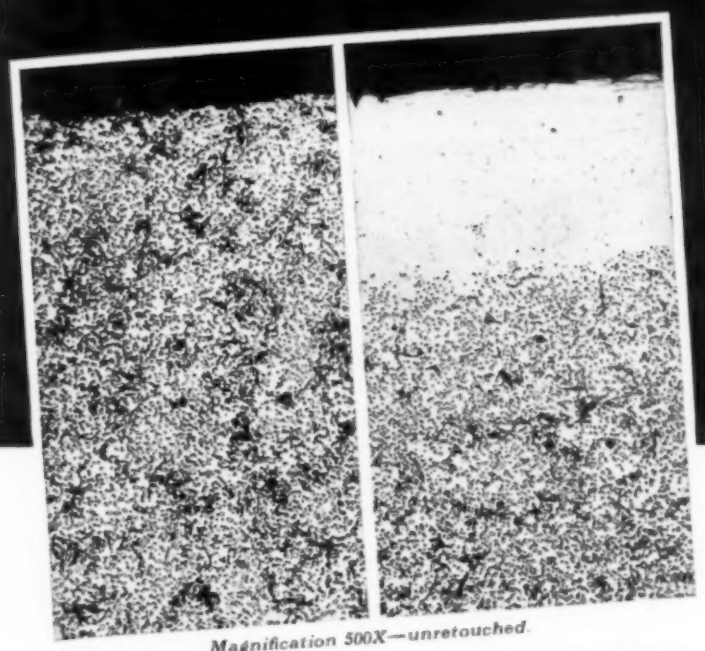
Horace C. Knerr

E. M. Schrock

S.A.E. 52100 BALL BEARING STEEL

SCALE-FREE HARDENED

WITHOUT "Decarb" USING ENDOGAS



Magnification 500X—unretouched.

1. ENDOGAS SCALE-FREE HARDENING SHOWS NO DECARBURIZATION

Micro-section on left, shows conclusively that no decarburization occurs when S.A.E. 52100—Ball Bearing Steel—is heat treated in ENDOGAS at 1500° F. for one hour. Now examine the micro-section on right.

2. ORDINARY SCALE-FREE HARDENING DECARBURIZES TO .005"

Upper white portion of micro-section, on right, shows that decarburization occurs to a depth of approximately .005" when S.A.E. 52100 is treated in an ordinary scale-free gas atmosphere under exactly the same conditions.

Ball Bearing Steel—S.A.E. 52100—is but one of a wide number of hard-to-handle steels which ENDOGAS will enable you to scale-free harden *without* decarburization. In fact, ENDOGAS now makes it possible to harden all S.A.E. steels without "decarb," under production conditions.

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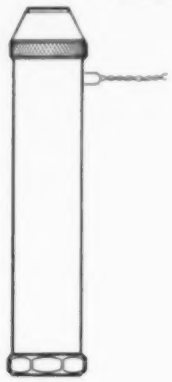

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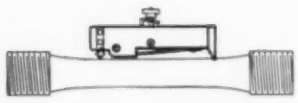

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ARC WELDORS

(Continued from page 183) paid to qualification of operators as well as to methods and materials.

Welding schools all over the country are now crowded with young men learning to weld. Vocational schools are showing more and more interest in teaching arc welding. That would not be true if those men did not sense an immediate or future demand for trained operators. In fact, many of us can remember the time when lack of proficient operators was one of the important elements of sales resistance encountered by manufacturers of welding equipment.

It seems to me that it would be better for all concerned to admit that best results from arc welding call for its use by skilled weldors who know something more about what they are doing and trying to accomplish than the mere mechanical manipulation of the welding arc. In the textbook used at our factory-operated, non-profit welding school we say: "Anyone with average intelligence, a steady hand, and a real desire to perfect himself in the art can readily learn to weld with the electric arc. To become an expert operator, however, requires something more than mere ability to manipulate the welding arc." That statement, of course, is directly opposed to the ideas promulgated in Mr. LINCOLN's letter.

Continuing the quotation from our textbook: "The man who has had previous training and experience in some mechanical trade will develop more quickly into a proficient welding operator than the man without such training or experience. An experienced gas weldor will find it extremely easy to become proficient with the arc due to his knowledge of metals, welding heats, etc."

In other words, while admitting the desirability of using trained operators, we try to point out the fact that it is not difficult to develop them, if none are available to the employer planning to adopt arc welding. Even where procedure control is so far advanced that little is left to the discretion of the welding operator, I personally believe that better welding may be expected when the operator knows what it is all about.

W. J. CHAFFEE